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AERONAUTICAL ENGINEERING REVIEW

JUNE 1953

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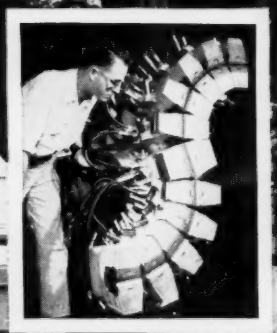

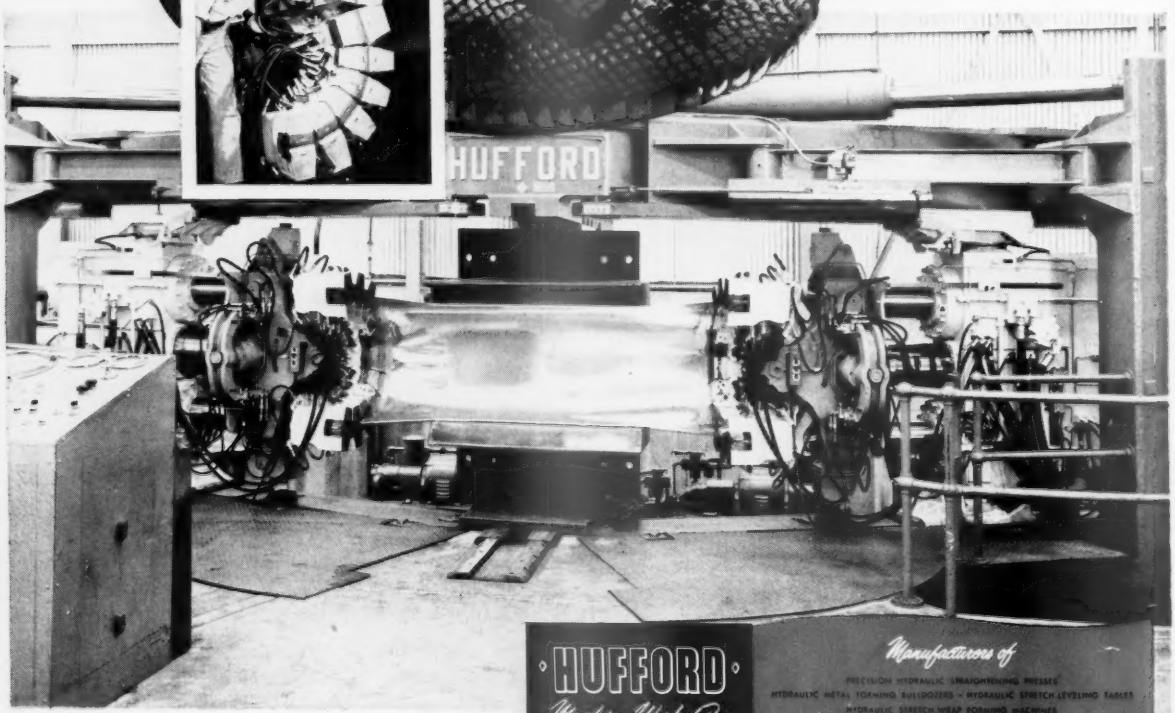

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Cover—A Navy FJ-2 Fury is shown in this picture as it is being catapulted from the deck of the U.S.S. "Coral Sea." The FJ-2 is being produced in quantity by North American Aviation, Inc., at the company's plant in Columbus, Ohio.

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SUBSCRIPTION RATES

Aeronautical Engineering Review: United States and possessions, 1 year, $3.00; single copies, $0.50. Foreign countries including Canada (American Currency Rates), 1 year, $3.50; single copies, $0.50.

Entered as second-class matter at the Post Office, Easton, Pa., April 29, 1942. Acceptance for mailing at a Special Rate of Postage as provided for in the Act of August 24, 1912.

Publication Office: 20th & Northampton Streets, Easton, Pa.

Editorial Office: 2 East 64th Street, New York 21, N. Y. Notices of change of address should be sent to the Institute at least 30 days prior to actual change of address.

Statements and opinions expressed in the Aeronautical Engineering Review are to be understood as individual expressions and not those of the Institute.

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AERONAUTICAL ENGINEERING REVIEW

Vol. 12 **JUNE, 1953** **No. 6**

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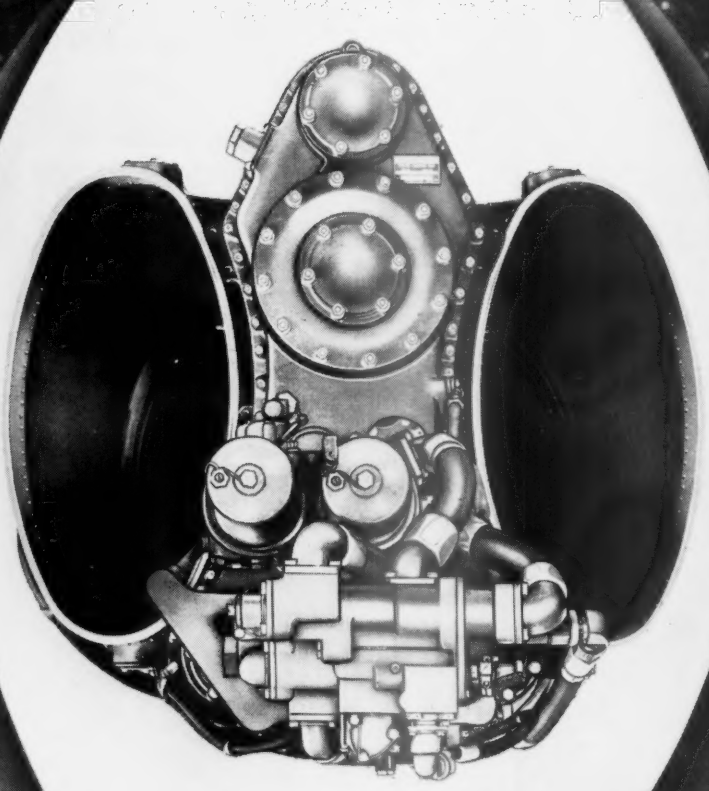
Published Monthly by the Institute of the Aeronautical Sciences, Inc.

HIGHLIGHTS IN *Jet Engineering*

New jet engine designs further reduce frontal area



I.A.S. News Notes

June 1953

LEMAY TO SPEAK AT SUMMER MEETING DINNER

The guest of honor and principal speaker at the forthcoming I.A.S. Annual Summer Meeting Dinner will be General Curtis E. LeMay, USAF, Commanding General, Strategic Air Command, USAF. This dinner will be held at the Hotel Statler in Los Angeles on July 15.

****

I.A.S. STAFF CHANGES

On April 15, three I.A.S. staff members were appointed to new positions. These were: Thomas J. Meskel, who became Assistant Secretary of the Institute; L. J. Prezzano, who assumed Mr. Meskel's former position as Manager of Member Services; and John J. Glennon, who was named Librarian of the New York Headquarters. Mr. Glennon had been Acting Librarian.

****

DELEGATES TO INTERNATIONAL AERONAUTICAL CONFERENCE

The Institute of the Aeronautical Sciences will be represented by 120 delegates at the forthcoming Fourth International Aeronautical Conference in London, England. This number is exclusive of any U.S. military personnel who will attend.

****

THE 1953-1954 RAeS PRESIDENT

Sir William S. Farren, FIAS, FRAeS, was installed on May 7 as the 1953-1954 President of The Royal Aeronautical Society. Sir William is Technical Director of A.V. Roe and Company, Ltd., of England.

****

NECROLOGY

Mark Andrew Klinger, Engineer, Piasecki Helicopter Corp., March 29.

****

NATIONAL MEETINGS CALENDAR

July 15-17 Annual Summer Meeting and Honors Dinner, Los Angeles, Calif.
Sept. 7-18 Fourth International Aeronautical Conference, London, England
Dec. 17 Seventeenth Wright Brothers Lecture, U.S. Chamber of Commerce Building Auditorium, Washington, D.C.

****

I.A.S. News Notes (con't.)

WINNERS OF FIRST SOUTHWESTERN STUDENT COMPETITION

The First Southwestern Student Competition, sponsored by the Texas Section, was held in Fort Worth on May 6-9 and was attended by students and faculty from eleven colleges. The following students were selected as winners in the Undergraduate Division: First Prize, F. W. Fenter, University of Texas; Second Prize, Richard Schapker, Parks College; Third Prize, J. M. Firebaugh, Texas A. & M.; and Honorable Mention, Fred Smith, University of Oklahoma, and Robert R. Wolfe, University of Tulsa. The Graduate Division winners were: First Prize, Harry L. Clements, University of Wichita; and Second Prize, Wilbur Light, University of Oklahoma.

****

NEW I.A.S. CORPORATE MEMBER

Ciba Company, Inc., 627 Greenwich Street, New York 14, New York.

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CALENDAR OF SECTION MEETINGS

June 3--Toronto Section: Elms Golf and Country Club, Annual Meeting; Dinner, 7:00 p.m. Films to be shown.

June 12--Chicago Section: Glenview Naval Air Station. Annual election of officers. Hour, subject, and speaker unknown at press time.

June 12--Hagerstown Section: Location unknown at press time. Meeting, 8:00 p.m. "The Controlled Stall and Application of Airplane Stability Test to Automobiles" by William F. Milliken, Jr., Manager, Flight Research Department, Cornell Aeronautical Laboratory, Inc. Movies of the American Sports Car Association's Watkins Glen Road Race to be shown.

June 18--Baltimore Section: Levering Hall, The Johns Hopkins University. Annual Dinner Meeting, approximately 6:30 p.m. "Major Problems of the Aircraft Manufacturing Industry" by Adm. D. C. Ramsey, USN (Ret.), President, Aircraft Industries Association. New officers to be installed.

June 18--Los Angeles Section: I.A.S. Building. Dinner Meeting (tentative).

June 18--San Francisco Section: Ramor Oaks, Atherton, Calif. Joint Meeting with American Rocket Society's Northern California Section. Hour unknown. "Possibilities of Space Travel" by William W. Kellogg, Boeing Airplane Company

June 18--Twin Cities Section: American Legion Club, Minneapolis. Dinner, 6:45 p.m.; Meeting, 8:00 p.m. "Development of High speed Aircraft" by Dr. Alexander Lippisch, Chief, Aeronautical Research Laboratory, Collins Radio Company

June 25--Los Angeles Section: I.A.S. Building, Specialist Meeting (tentative).

****

IAS News

A Record of People and Events of Interest to Institute Members

Preliminary Announcement of 1953 Annual Summer Meeting

Meeting to Be Held July 15 to 17; Replica of Wright Brothers Airplane to Be Dedicated and Installed in IAS Los Angeles Building

THE 1953 ANNUAL SUMMER MEETING of the Institute of the Aeronautical Sciences will take place at the IAS Western Headquarters Building, 7660 Beverly Blvd., Los Angeles, from July 15 through July 17. The hosts for the meeting will be, as usual, the executive and general membership of the Los Angeles Section. The 1953 Chairman of this Section is Harold Luskin, Assistant Supervisor of Aerodynamics for Research, Douglas Aircraft Company, Inc.

▶ **The Dinner**—The 1953 Annual Summer Meeting Dinner will be held on the evening of July 15 at the Hotel Statler in Los Angeles. On display that evening at the hotel will be a full-scale model of the Wright Brothers airplane, which was built through the combined efforts of aeronautical companies on the West Coast. The replica will be formally dedicated at the dinner in a ceremony conducted by Lt. Gen. James H. Doolittle, USAF (Ret.), Chairman of the National Committee to Observe the Fiftieth Anniversary of Powered Flight. General Doolittle is an IAS Past-President, Honorary Fellow, and Founder Member, as well as Vice-President of Shell Oil Company. At the end of the evening's program, the replica will be moved to the local IAS building, where a brief installation program will occur on the morning of July 17.

The Thurman H. Bane Award and The Octave Chanute Award will be presented during the dinner to their respective recipients. These Award winners will be announced subsequently. The 1953 IAS President, Charles J. McCarthy, Vice-President of United Aircraft Corporation, will make the presentations of the Awards.

▶ **Tentative Program**—A total of five technical sessions are expected to be held during the 3-day meeting. Two of these are scheduled for Wednesday; one, for Thursday; and two, for Friday. The Thursday Session is to be held in the evening and, like the field trip planned for that same day, will require proper military clearance. The other four sessions will be open to all persons, and the papers to be presented at each of these four open sessions are as follows:

Wednesday, July 15

Aerodynamics — Morning Session

Wing-Body Interference at Subsonic and Supersonic Speeds: Survey and New Developments—H. R. Lawrence and A. H. Flax, Cornell Aeronautical Laboratory, Inc.

Energy Approach to the General Aircraft Performance Problem—E. S. Rutowski, Douglas Aircraft Company, Inc.

A Study of Hypersonic Small-Disturbance Theory—Milton J. Van Dyke, Ames Aeronautical Laboratory, NACA.

A Vector Method Approach to the Analysis of the Dynamic Lateral Stability of Aircraft—Leonard Sternfield, Langley Aeronautical Laboratory, NACA.

Propulsion — Afternoon Session

Spreading of Supersonic Jets in Supersonic Streams—J. G. Wilder and K. Hindersinn, Cornell Aeronautical Laboratory, Inc.

Afterburners—Are They Worth While?—F. C. Newton, Douglas Aircraft Company, Inc.

A Discussion of Development, Experience, and Design Problems Associated with Several Types of Variable-Area Exit Nozzles—J. S. Winter and R. G. Laucher, Marquardt Aircraft Company.

Techniques for Determining Thrust in Flight for Airplanes Equipped with Afterburners—L. Steward Rolls and C. Dewey Havill, Ames Aeronautical Laboratory, NACA.

Friday, July 17

Wright Model Installation — Morning

Installation program of full-scale replica of the Wright Brothers Airplane at the IAS Western Headquarters Building.

The Engineering Development of the Wright Brothers Airplane—R. B. Johnston, The RAND Corporation.

Structures — Morning Session

Fatigue Life of Thick-Skinned Tension Joints—E. W. Thrall, Douglas Aircraft Company, Inc.

Minimum Weight Wing Design—A. L. Kolom, North American Aviation, Inc.

Warping of Thin Shell Wing Structure—Joseph A. Wise, University of Minnesota.

Helicopter Design—Propulsion Applications — Afternoon Session

Reciprocating Engine: McCulloch YH-30—Speaker not given.

Turbojet Engine: Hughes XH-17—T. F. Fletcher, Project Engineer, XH-17, Hughes Aircraft Company.

Pulse-Jet Engine: American Helicopter XH-26—Speaker not given.

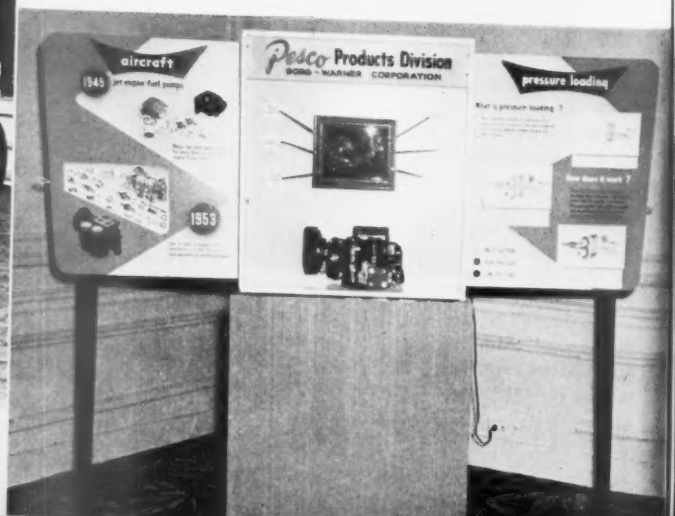
Ram-Jet Engine: Hiller YH-32—Harvey Holm, Project Engineer, XH-32, Hiller Helicopters.

Rocket Engine: Rotor-Craft "Pinwheel"—Speaker not given.

(A static helicopter display will be located in the parking lot adjacent to the IAS building.)

▶ **Program Planning**—The planning for this meeting has been carried out by the Los Angeles Section's Program Committee. This committee, under the direction of its Chairman, Welko E. Gasich, of The RAND Corporation, has gone to infinite pains to ensure the success of the meeting. Final programs should be in the mail to IAS members by mid-June.

Cleveland, Ohio, March 13, 1953

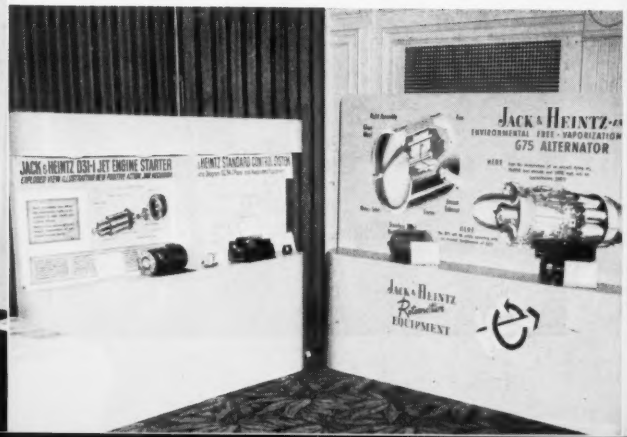


Exhibition Booths

Flight Propulsion Meeting

The security-classified nature of the Eighth Annual Flight Propulsion Meeting precludes any report of the technical sessions. However, it is safe to say that the more than 500 members who attended the meeting felt amply repaid for their trip to Cleveland. As usual, the boys and girls from the NACA Lewis Flight Propulsion Laboratory, the Cleveland-Akron Section members, and the local companies who sponsored exhibits and the predinner social hour did a splendid job of putting on a good show.

The photos on the opposite page, and the two at the bottom of this one, show sections of the displays, which created considerable interest. Speakers at the morning and afternoon technical sessions are grouped directly below. At the left IAS President Charles J. McCarthy presides at the evening dinner where Rodney Banks was the guest of honor and principal speaker. Mr. Banks' address on "The Birth of an Engine" will be found elsewhere in this issue.



Fourth Plasticity Symposium

The Fourth Plasticity Symposium, to be held at Brown University on September 1–3, 1953, will cover three principal topics: (1) stress-strain relations (perfectly plastic, work-hardening, viscoelastic, and viscoplastic materials); (2) distribution of stress and strain in bodies exhibiting inelastic properties (static and dynamic problems and infinitesimal and finite deformations); and (3) structural analysis and design in the inelastic range (limit analysis, static and dynamic loading, shakedown, and inelastic buckling). Papers will be presented by American and Foreign experts.

Certain sessions will be sponsored by Brown University in cooperation with the American Society of Civil Engineers' Engineering Mechanics Division. The remaining sessions will be sponsored jointly by Brown and the Office of Naval Research.

For further information, please contact: Prof. Harry J. Weiss, Graduate Division of Applied Mathematics, Brown University, Providence 12, R.I.

Two More Firms Join IAS

Brandt Manufacturing Company, of 9784 Bellanca Street, Los Angeles, and Robert Hewitt Associates, of 439 Madison Avenue, New York City, have joined the Institute of the Aeronautical Sciences as Corporate Members.

▶ **Brandt Manufacturing Company** is a partnership in which Homer Brandt is the active Managing Partner and W. M. Gillette, Jr., is Chief Engineer and Plant Manager in charge of operations.

The company, currently employing approximately 50 men, does all of its work in the aeronautical field. This work falls into four categories: aircraft tooling, fabrication of holding and handling fixtures, production machine parts, and lofting and construction of all types of aircraft templates.

The aircraft tooling consists of the construction of form blocks, dies, and other tooling items which are used by Douglas Aircraft Company, Inc., and other air-frame companies in the fabrication of air-frame parts. The handling fixtures consist mostly of precision welded parts. In making production machine parts, the company's own equipment is used to do precision machining of actual aircraft parts from raw stock, sheet, bar, castings, or forgings.

As a part of the production activity, Brandt Manufacturing Company works closely with the engineering personnel of large air-frame companies. In many instances, the original engineering specifications received by Brandt have been revised or refined.

▶ **Robert Hewitt Associates** is an executive-aircraft consulting firm that, since World War II, has devoted its efforts to the many phases of sales, conversion, and management of corporation executive multiengine aircraft.

Robert Hewitt Associates acts as consultant to corporations that are now owners of executive aircraft and to firms that are contemplating such means of transportation for their management. Studies and analyses are made to determine transportation requirements, consider suitable types of aircraft for the specific purpose, justify the program financially, determine policies and procedures for efficient traffic control, and furnish standards for efficient and economical operation of the equipment.

This consulting company claims to be a pioneer in this field from the standpoint of considering the principle and purpose of a corporation's aircraft. Robert Hewitt Associates was formed to provide a service that would promote the function of the corporate aircraft and would prove its use to management as a profit-making tool.

Some of the session speakers and panel members at the recent symposium in Los Angeles on "Frontiers of Man-Controlled Flight" are shown in the picture below. *From left to right,* they are: *(seated)* Major Charles E. Yeager; Edgar Schmued; John R. Poppen, Symposium Chairman; Alfred M. Mayo; and Heinz Haber. *(Standing)* Stanley N. Roscoe, Neil D. Warren, Charles F. Lombard, Laurence E. Morehouse, Herman P. Roth, Stanley Lippert, W. V. Blockley, Harold Luskin, John H. Mathewson, and Konrad Buettner.

Photo: H. D. Williams, U.C.L.A.

Los Angeles Section Cosponsors Flight Symposium; Proceedings to be Published

A symposium entitled "Frontiers of Man-Controlled Flight" was held on April 3 at the IAS building in Los Angeles. More than 300 engineers and aviation medicine specialists attended.

The symposium was presented by the Institute of Transportation and Traffic Engineering and University Extension, University of California at Los Angeles, in cooperation with the Aeromedical-Engineering Association and the IAS Los Angeles Section. Seventeen papers were presented in the three daytime sessions. In the evening, a panel discussion of the symposium took place immediately after a dinner, which was served in a Los Angeles restaurant. The panel was composed of the symposium speakers.

The proceedings of the symposium are now being published and will soon be available in a paperbound lithoprinted book for the nominal charge of $2.00. Those persons interested in obtaining copies of the proceedings may write to: University of California Press, Berkeley 4, Calif.

N. J. Hoff to Present RAeS Wright Lecture

Dr. Nicholas J. Hoff, FIAS, FRAeS, Professor and Head of the Department of Aeronautical Engineering and Applied Mechanics, Polytechnic Institute of Brooklyn, has accepted the invitation extended by The Royal Aeronautical Society to deliver the Forty-First Wilbur Wright Memorial Lecture. This lecture, which is an annual RAeS presentation, will be given on September 14. An unusually large IAS representation is expected at this lecture, since it will occur during the Fourth International Aeronautical Conference in London, England, on September 7–17.

Dr. Hoff, who has had numerous articles on aircraft design, structure, and engineering published in American and foreign technical journals, has been associated with the aeronautical field for about the past 25 years. Graduating in 1928 from the Federal Polytechnic Institute, of Zurich, Switzerland, with the degree of Diplom-Ingenieur, he went to work the following year in his native Hungary as Designer and Stress Analyst in the Aircraft Division of Manfred Weiss Aircraft and Motor Works, Ltd. He left there in 1939 to emigrate to the United States where he became Research Assistant at Stanford University and worked under Professor Timoshenko toward a Ph.D. degree in Engineering Mechanics. This degree was awarded to him in 1941. He joined the faculty of the Polytechnic Institute of Brooklyn in September of 1940. Five years after coming to this country, he became an American citizen.

News of Members

▸ **Guy L. Bryan, Jr.** (AF), Professor of Aeronautical Engineering, The Johns Hopkins University, has become a Consultant on Structural and Special Design Projects for Van Zelm Associates.

▸ **William J. Cushing** (M), recently released by the Navy to inactive duty, has formed his own company, William J. Cushing and Associates, to act as manufacturers' representatives. The company is located in the Reibold Building, Dayton, Ohio. Mr. Cushing's last assignment in the Navy was as Special Project Officer, Aircraft Production Resources Agency, Wright-Patterson AFB, Ohio.

▸ **Ralph S. Damon** (F), President, Trans World Airlines, Inc., was recently elected a Director of the New York Telephone Company.

▸ **Martin Goland** (AF), Associate Director for Engineering, Midwest Research Institute, has been reappointed to serve as Chairman of the NACA Subcommittee on Vibration and Flutter and as a member of the NACA Committee on Aircraft Construction.

▸ **Dr. Peter Kyropoulos** (M), Associate Professor of Mechanical Engineering, California Institute of Technology, has been appointed to Pacific Airmotive Corporation's 10-man Research Advisory Committee. This group acts as consultant on various research and development projects of the corporation.

▸ **Dr. Clark B. Millikan** (HF), Professor of Aeronautics and Director of the Guggenheim Aeronautical Laboratory, California Institute of Technology, was recently named to serve on Pacific Airmotive Corporation's Research Advisory Committee. This group, which is composed of ten scientists and engineers, acts as consultant on various research and development projects of the corporation.

Oliver E. Rodgers (M) has been named Chief Engineer of Packard Motor Car Company's Jet Engine Division. Mr. Rodgers, a graduate of Harvard University, was formerly Assistant Manager, Gas Turbine Division, Westinghouse Electric Corporation.

▸ **Howard F. Rough** (M), retired from Government service on last January 31 after 25 years with the CAA and its predecessor organizations. Since about mid-February, Mr. Rough has been serving without remuneration as the Head of a special Air Coordinating Committee group for Government participation in the year-long celebration of the Golden Anniversary of Powered Flight.

Members on the Move

The purpose of this section is to provide information concerning the latest affiliations of IAS members. All members are therefore urged to notify the News Editor of changes as soon as they occur.

William B. Bergen (AF), Vice-President—Operations, The Glenn L. Martin Company. Formerly, Vice-President and Chief Engineer, Martin.

Raymond L. Bisplinghoff (AF), Professor, Department of Aeronautical Engineering, Massachusetts Institute of Technology. Formerly, Associate Professor, Department of Aeronautical Engineering, M.I.T.

Harold G. Brilmyer (AF), Vice-President in charge of Research, Huck Manufacturing Company. Formerly, Assistant to the President, Huck Manufacturing.

David Eisenberg (TM), Design Engineer, Canoga Corporation. Formerly, Engineering Designer, Hughes Aircraft Company.

John A. Gillies (M), Chief Engineer, Canadian Pacific Airlines, Ltd. Formerly Technical Assistant to Manager, Aviation Sales Department, Imperial Oil Ltd.

Myron B. Gordon (AF), now Chairman of the Board, Flight Refueling, Inc.

William R. Haney, Jr. (M), Field Engineer, William R. Whittaker Company, Ltd. Formerly, Project Engineer, Bendix Products Division, Bendix Aviation Corporation.

Wilfred C. Hugli, Jr. (M), Assistant Director, Plans and Coordination, Experimental Towing Tank Laboratory, Stevens Institute of Technology. Formerly, Executive Engineer, Experimental Towing Tank Laboratory, Stevens.

Martin A. Jackson (M), Project Engineer, Van Zelm Associates. Formerly, Assistant Group Engineer, The Glenn L. Martin Company.

Jacques A. Kirk (M), Wind Tunnels Department, The de Havilland Aircraft Company, Ltd., England. Formerly, Wind Tunnels Superintendent, Short Brothers & Harland, Ltd., Northern Ireland.

Garth C. Ladd (TM), Research Associate, Department of Aeronautical Engineering, Rensselaer Polytechnic Institute. Formerly, Aerophysics Engineer, Fort Worth Division, Consolidated Vultee Aircraft Corporation.

John L. Lull (TM), Design Engineer, Consolidated Vultee Aircraft Corporation.

(*Continued on page 66*)

Dr. A. M. Ballantyne, Secretary
The Royal Aeronautical Society

Editorial

Fourth International Aeronautical Conference

As this is written, most of the arrangements for the Fourth International Aeronautical Conference with Britain's Royal Aeronautical Society have been finalized, papers are in the last stages of revision (some of them are actually in hand), and some hundred odd IAS members (some with their wives and families) are looking forward to departure time.

As was the case for the two previous Conferences in England (1947 and 1951) the IAS delegation represents a notable cross section of America's aviation industry. There are few areas of major interest in the broad field of the aeronautical sciences which are not covered by our group. Our colleagues of Britain's aviation industry will have little trouble in finding top-level "opposite numbers" from this side with whom to confer on problems of mutual interest. A great deal of the value of such meetings comes from the person-to-person contacts that are made outside of the technical sessions. Much of the real interchange of ideas goes on over tea and luncheon tables (—or even at bars!). Subsequent correspondence at long ranges is always made easier if one is personally acquainted with one's correspondent.

We have just had news of the election of Sir William Farren as President of The Royal Aeronautical Society. To many of us, Sir William is an old friend. He has visited on this side many times (the last time only 2 months ago). He knows something of our peculiarities and can make due allowance for them. He and IAS President McCarthy already have an acquaintance of long standing which will be extremely useful during our coming visit. We all have pleasant memories of the cordial interchange of 1951 between the two Presidents of that year, Major Frank Halford and Rear Adm. L. B. Richardson. A thorough understanding at the Presidential level does much to make the entire relationship smooth and harmonious. We are certain that the Fourth International will be in excellent hands.

The Brighton Conference of 1951 was the "swan song" of our old friend Laurence Pritchard (and a good song it was!) as he retired after many years as Secretary of the RAeS. His successor, Dr. A. M. Ballantyne was among those present at Brighton. Many of us had an opportunity to meet him then. Some of us who are concerned with common problems have been in almost continuous correspondence with him in recent months. We are all looking forward to an opportunity to learn to know him better. We hope that before too long he will have occasion to pay us a visit on this side of the Atlantic.

We are all delighted at the response of the IAS membership to this year's Conference. The interest on the part of individuals and of companies has been most striking. The large participation by the Armed Services and other Defense agencies is particularly gratifying. It all means that the preceding three Conferences have been successful. They have established a pattern for the improvement of international good will at the scientific and engineering levels. We are all looking forward to a continuation of the kind of collaboration between aeronautical people on both sides of the Atlantic which has been evidenced on these occasions. As long as the two great English-speaking nations of the world see eye to eye on such matters the hope of a free world for free men cannot be dimmed. S. P. J.

The Next Half Century

Luncheon Talk at 21st IAS Annual Meeting, New York, January 27, 1953

*by C. C. Furnas**

Cornell Aeronautical Laboratory, Inc.

Introduction

HALF-WAY HUTS ON MOUNTAINS, mid-centuries, and the seventh-inning stretch have one thing in common—everybody stands up and takes a look around in both directions: recapitulation and prognostication. As we enter the 50th anniversary year of the first heavier-than-air flight, we may be fortunate in that it approximately coincides with the midpoint of that arbitrary block of time, the 20th Century. During the past couple of years, there has been a spate of exposition from the historians, scientists, economists, sociologists, and statesmen, trying to link where we have been with where we are probably going. The Pollyannas and the prophets of doom are having a fine time battling it out for first place, and they are playing to a good house. Perhaps it would be in order for the aeronautical fraternity to get into the act, in a small way, and foretell what the next half century may bring forth.

Though some like it and some do not, there is little question that the world has changed more rapidly during the past half century than during any other equal period in history. A strong case could be made for the thesis that the airplane has been the most important single instrument in this revolutionary process. The primary impact has not been due to commercial activities—substantial though they may be—but rather to past and potential military utilization. Essentially, the airplane is the instrument that makes a truly total global war possible—a war that would involve the entire resources and populations of most of the world. This has had, and will continue to have, a tremendous impact on the economics, politics, and everyday life of all of the nations of the world. Hence, the importance and interest in speculation on the sort of devices and systems the second half century of aviation may bring forth.

Since the current actuarial tables indicate the probability that I shall survive another 50 years to be substantially less than 0.001, I can make predictions with little fear of ever being faced with a final tabulation of my errors.

Fuels

High-Energy Chemical Fuels

Reliable, available, and relatively inexpensive liquid fuels from petroleum have played an essential part in making the airplane what it is today, and it is doing quite a job. However, if anyone will take a slide rule in hand and go through a little labor of calculation, he will inevitably arrive at the conclusion that the airplane could do some really wonderful things if it just had a fuel that packed more energy per pound than gasoline. We have made remarkable progress in the performance of the airplane by improving engine efficiency and overall propulsive efficiency, but it appears that we are probably approaching the limit of the possibilities along this line. The engineer casts envious eyes at the lightest of all the chemical elements, hydrogen, which, upon combustion, releases about three times as much energy per pound as does gasoline. But hydrogen has unfortunate physical properties for aviation use. It persists in remaining a light gas at ordinary temperatures and thus requires heavy and bulky high-pressure containers for storage. If it is cooled down to 423° below zero Fahrenheit at atmospheric pressure, it liquefies, but even then it is less than one-tenth as dense as gasoline. So the volume required and the weight of containers for either gas or liquid, per unit of energy, are unduly large. It is

* Director.

presently of at least potential interest to rocketeers, but for the ordinary garden variety of aircraft, it seems to me that hydrogen will never be a feasible fuel, from either the economic or engineering point of view.

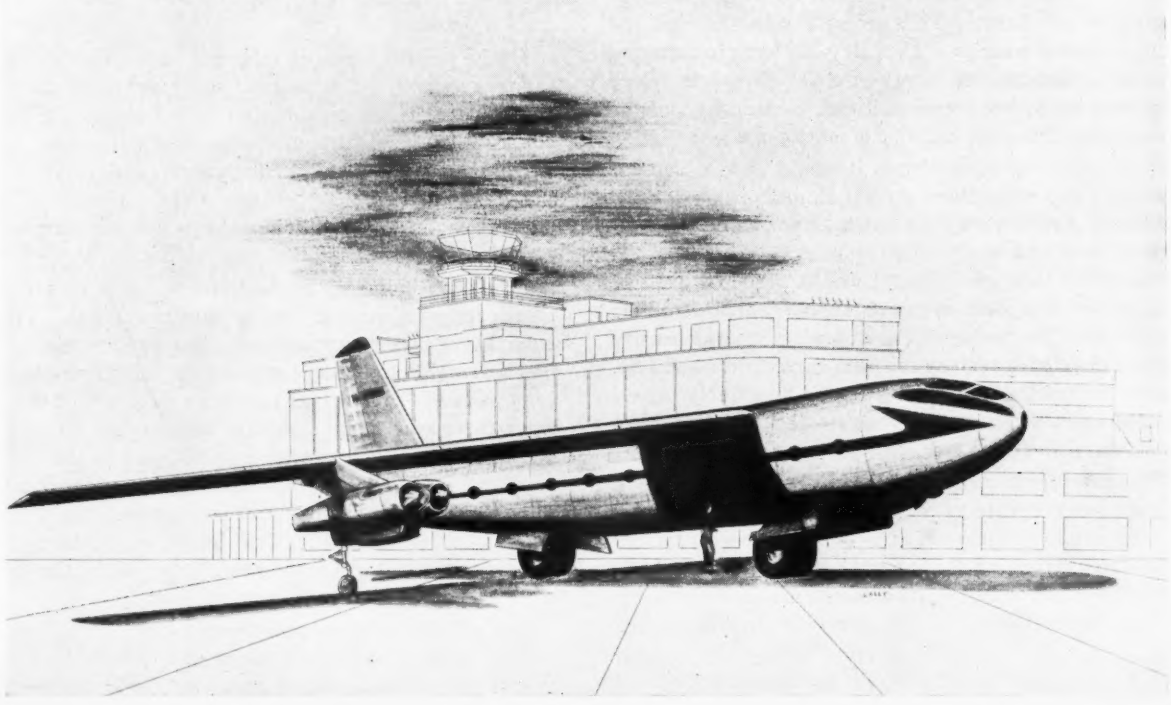
There are a few chemical elements (other than hydrogen) and at least several compounds that have a somewhat greater heat of combustion per pound than has gasoline. These offer intriguing possibilities, for even a 25 or 50 per cent increase in the energy available per pound of fuel could lead to much greater proportional increases in aircraft performance. Since many people have thought about this and since the potential gains are great, it is probable that over the years to come the possibilities will be explored to the fullest. If any such satisfactory fuels are developed, it can be anticipated that they will have at least some military uses. For extensive military or commercial use, however, the cost, including the credit for increased performance, would have to be approximately equal to that which could be realized from gasoline or other liquid fuels. I expect inexpensive liquid fuels from either petroleum or coal to be in good supply for another 5 decades. Knowing something of the inherent cost of making entirely synthetic chemical compounds, I will be quite surprised if special fuels will play a major role in inhabited aircraft within the next half century. As you can see, I am being disgustingly conservative at this point. It should be pointed out, however, that eventually, when the fossil fuels (petroleum and coal) are gone, we will have to synthesize our fuels, probably with the aid of artificial photosynthesis. When we are driven to this, we may well find it economical and feasible to carry the synthesis through to the high-energy types; but the economic forces put this a substantial distance in the future.

Nuclear Fuels

The well-publicized project on the nuclear propulsion of aircraft has led some people to believe that the liquid-fuel-propelled airplane will be a dodo within a generation. My own opinion is that the project on nuclear propulsion will eventually be successful and that there will be some extremely large nuclear-propelled aircraft built which will have practically infinite range and any desired speed but that their use will be confined to special military purposes. My pessimism is based on three things—hazards, inherent complications, and necessary weight, the last being the most important. Unless some new principle of physics is discovered, we will forever be burdened with the necessity of having truly heavy masses of materials for shielding any human beings in the close vicinity from the radiation of an operating nuclear reactor. The weights that are involved in shielding are so great that it seems to relegate the aircraft application of nuclear energy to special and unusual cases. So, again, on the matter of nuclear energy, I seem to be on the conservative side. I should add, however, that, as far as stationary power plants are concerned, or ship propulsion, nuclear energy has tremendous possibilities and probably a much brighter future than for use in aircraft.

In general, then, it is my opinion that, in looking to the next half century, it is the most realistic course to

Based on design studies by Boeing Airplane Company, this drawing shows details of what the jet transport of the future may look like. This 500-m.p.h. jet transport would be powered by four turbojet engines, would have a tandem-type landing gear and sharply sweptback wings and tail surfaces, and would be designed for operation from present airports.



confine our considerations to the use of something like the same type of liquid fuels we are using at the present time.

Propulsion Plants

Heat Engines

Looking ahead for 5 decades, I do not see that we will, in that time, be able to dispense with the use of heat engines of some sort in the propulsion of aircraft. Though it is conceivable that some means might be discovered for the direct conversion of nuclear energy at high efficiency into electrical energy, the laws of physics seem to be particularly stubborn on this score, and there is no immediate prospect that the physicists are going to be able to change the situation. Hence it appears that we are going to be confined to the use of heat engines for the foreseeable future.

It seems to be the consensus that the reciprocating engine has about had its day, and I have no evidence to gainsay this, but I do believe that a number of reciprocating engines will be around for a long time, at least in the smaller sizes for occasional use such as in light aircraft.

For the bulk of the airplanes of large to moderate size, both military and commercial, I visualize that the gas turbine will be the basic power plant. At the present time, the straight turbojet power plant is coming into its own, with the turbopropeller proponents struggling mightily to get into the act. In forecasting the probable outcome of this struggle, it is well to keep the laws of momentum in mind, which tell us that the turbojet is doing it the hard and inefficient way (unless it is traveling at truly high speeds) for the simple reason that it is handling relatively small quantities of air to produce its thrust. This necessarily means that the high residual velocity of the exit gases leads to throwing away a great deal of energy into the empty air, which in turn leads to a low overall thrust efficiency and the well-known fuel consumption of jet engines.

Without going into detail, it would appear that for every flight speed there is an optimum airflow-to-fuel-consumed ratio that is an optimum for a given power-plant weight-per-pound-of-thrust. This ratio would change for each speed, and, hence, a prime requisite of the propulsion plant should be flexibility in air-handling capacity. As far as I know, such a comprehensive generalized study has never been carried out, but I believe it should be done. It would probably reveal some valuable information about the desirable basic characteristics of power plants.

In addition to air-handling flexibility, the propulsion plant for moderate to high speeds should be equipped to take full advantage of ram-pressure recovery, which indicates shrouding or cowling of some sort which is not present in the conventional propeller installation.

The above two points (flexibility in air-handling capacity and ram-pressure recovery) lead me to the opinion that neither the turbojet nor the turboprop will be the eventual clean-cut winner. The propulsion plant most likely to have extensive use will be that sadly neglected child, the ducted fan, or combination jet, or whatever name you wish to put on it. Basically it will be built around a gas turbine, but one that, for propulsion purposes, will handle more air than is required for operating the turbine. Such a power plant will be the backbone of the business, although, for manned aircraft traveling at supersonic speeds up to a Mach Number of 2, the straight turbojet may be the optimum power plant, everything considered.

For flights of any substantial duration of Mach Number 2 or above, either pilotless or inhabited aircraft, the ram-jet comes into its own. Here, however, some combination device is called for, because the ram-jet must be boosted up to its operating speed. This, again, then indicates the desirability of some power plant of the general variety of the ducted fan for most applications.

Speed

Like the dinosaurs, men seem occasionally to overdo things in their evolutionary processes and find that the superlative versions become obsolete, the final accepted model being something less than the possible ultimate. Commercial ocean liners are not getting larger any more; the biggest ones have been found to be uneconomical. The longest-range gun on record was the 75-mile variety, which the Germans used to bombard Paris in 1918; but, even from the military point of view, it didn't pay and was never attempted again. I have a strong feeling that the same sort of situation is developing in the category of the speed of manned aircraft, both military and commercial, and that eventually the optimum will be found to be somewhat less than we now have in mind.

In the present frame of reference and tradition, the military aviator will sacrifice almost everything else to speed, but it is conceivable that he is treading the obsolescing path of the medieval knight-in-armor on horseback. The heavily encumbered and expensive knight became obsolete because of the perfection of a simple weapon, the English longbow, which was operated by a slow-moving but skillful man on foot.

In passing judgment on the trend of speed, it is necessary again to keep the laws of physics in mind. The cube law of power-required is stubborn and persistent, and although aerodynamic refinements and power-plant improvements have helped to modify its effects, it is always there and is the dominant factor after we have carried all refinements as far as possible. In the ultimate, then, when you vie for speed, you sacrifice other things and eventually come to the point of diminishing returns. It is my opinion that, before we get through with our emphasis on speed, we will have passed the optimum for military combat aircraft.

You will immediately pose the question—aren't you helpless in aerial combat if the enemy is faster? The answer for the future is that such need not be the case.

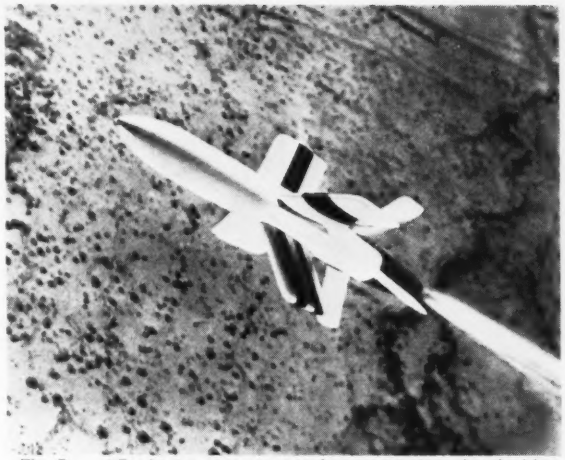
Referring again to the analogy of the armored knight and the foot soldier with the English longbow, the answer is to be found in the availability of new and effective weapons—namely, air-to-air guided missiles. They can supply the necessary final increment of speed, maneuverability, and rate of climb and let the airplane serve in an optimum fashion for what it truly is—namely, a carrier to get certain weapons somewhere in the vicinity of the target, quite analogous to battleships. Perhaps aircraft can do a better job in accomplishing this objective if they do not have to sacrifice everything else for speed.

Will we, then, be able to dispense entirely with the human being in military air combat and replace him with a variety of guided missiles? My answer to that is: No. The reason is simple: no matter how complex they become, guided missiles are essentially stupid. Though they may be built to do many clever and wonderful things and to be relatively selective in their action, they are not able to exercise the type of judgment needed in battle. Man is capable of exercising judgment because of the extensiveness of his equipment. His sensing and memory storage units (brain cells, if you choose) are numbered by the billion, and it is likely that this is the order of magnitude of units inherently required to do the job. For mobile, inanimate devices, the number of sensing units will probably have to be limited to a few paltry thousands, even though full use is made of transistors. Although we are well on our way to making the man obsolete in many functions, he will always be the focal point of operation of complete systems—military or otherwise—at least where the elusive entity of judgment is required.

Commercial Speeds

The speeds that are utilized in any form of commercial transportation represent an uneasy truce between the laws of physics and the pattern of economics. Though the laws of physics are immutable, the pattern of economics does change, so it is hard to make any definite prediction about optimum points in the future. The task is made somewhat simpler, however, by the fact that physical limitations on attaining high speeds of aircraft have been virtually removed during the last 2 decades, so the economic factors now make up the principal determinant. The economic optimum is the resultant of a battle among the cube law of the power-required for speed, fixed cost of operation, the degree of utilization of man power and equipment, and public demand for the commodity of speed. These parameters are common to any form of transportation. Aircraft, however, do have the advantage of a third dimension, which makes it possible to acquire additional increments of speed by going to higher altitudes, without substantial additional cost, in response to either public demand or weather conditions. This is particularly true for longer flights.

For the past 2 decades, the estimates of the students of air transportation of the economic optimum speed



The Ryan "Firebird," air-to-air missile, provided much valuable engineering data that are being used to design improved missiles.

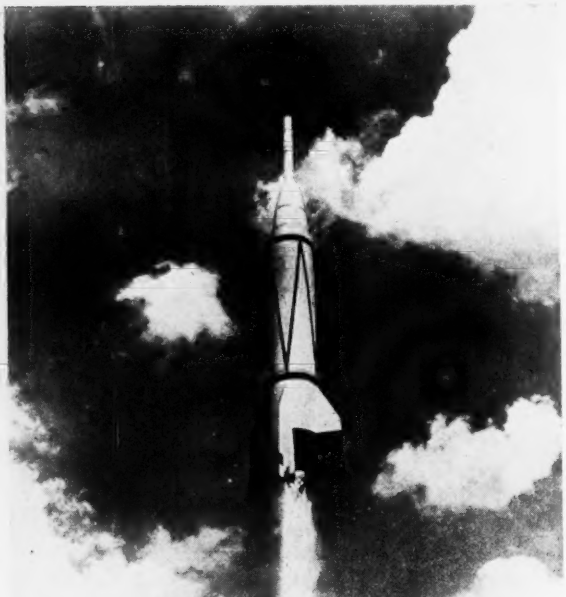
have been curiously close to the speed performance of the best commercial aircraft available at that time, indicating that there may be some element of rationalization in the process of arriving at the figure. However that may be, it is my opinion that the speeds that will be utilized for commercial operations within the next half century will not be in the realm of the fantastic. I cannot visualize regular commercial air liners traveling at supersonic speeds, even at extremely high altitudes. It costs too much, and there is too little to be gained. If I may venture an opinion, it would be that the commercial cruising speeds for long-distance flights will probably settle down in the neighborhood of 600 m.p.h., while for the shorter distances a prosaic 300 m.p.h. will prove to be adequate. This will represent substantial progress over the present but nothing really earth-shaking.

Helicopters

While I am being pessimistic on cruising speeds, it is a simple task to cut the estimate down still more for the truly short-haul traffic. In my opinion, a really substantial proportion of the intercity air traffic of the foreseeable future, for distances up to 200 miles, will be carried by helicopters at speeds not exceeding 200 m.p.h. For travel between adjacent large cities, with adequate downtown heliports, this will be the most rapid means of getting from here to there and, hence, will be the most used—for the short hops. The flying machines used will be helicopters of some sort, although perhaps they will be more graceful than the present specimens. However it may be adapted, it appears that the rotary-wing principle will be most practical for meeting the requirements of vertical landing and take-off, hovering, and high maneuverability.

What about convertiplanes? I solve that problem easily by including them in the above broad definition of "helicopters of some sort," provided they utilize the rotary-wing principle for take-off, landing, and hovering.

The helicopter will also grow steadily in popularity in the fields of specialized uses in hard-to-get-at places.



The "Bumper" two-stage rocket in flight.

This applies to a multitude of military operations, as well as civilian activities, such as prospecting, forest-fire fighting, rescue, power-line patrol, etc. It will also have a role in the private, garden variety of air transportation—although hardly to the extent that the enthusiasts imagine.

Safety and Reliability of Service

Safety and reliability of service are mentioned together because there are certain elements of opposition between these two parameters. The way to achieve 100 per cent safety with airplanes is to have zero reliability—namely, leave them on the ground. Conversely, if you are going to have 100 per cent reliability of air transportation, which means operating in any and all kinds of weather and probably with insufficient maintenance, then your safety record is going to be substantially less than 100 per cent.

The air lines have made truly remarkable progress during the past few decades in both reliability and safety. However, this is no cause for complacency; we still have a long way to go. While it is true that the safety record of the air lines, in terms of passenger fatalities per 100 million passenger-miles, over the past several years has been more than twice as good as that of private automobiles, it is also true that it has only been about one-tenth as good as the Pullman experience on the railroads. And while it is also true that the proportion of uncompleted, though scheduled, flights has been cut down to a fraction of what it was in 1930, the record of reliability is still far removed from that of the railroads in most parts of the country.

A critical survey of the safety record of the air lines in terms of passenger fatalities per 100 million passenger-miles indicates that we may have made no significant improvement during the last 7 or 8 years. Because so much thought and effort by both the manufacturers and operators is being put into the matter of safety, it may be that this 7- or 8-year record is only a plateau and that an era of greater progress in safety will soon be seen again. The scheduled commercial air lines have just turned in a remarkably good safety record for the calendar year 1952, which can give us a warm glow of satisfaction for the future as well as the present. Such optimism may, however, be based on erroneous assumptions, unless some really new approach is undertaken for dealing with the problems of air-transport safety. There is, in any human activity, some level of safety which, on the average, cannot be improved. Let us hope that we have not yet arrived at that level in air transportation, even though the current evidence may be against us. We can go on improving the reliability of components of aircraft ad infinitum, and still there will be some accidents. Occasionally there will be a sequence of failures of this and that, sometimes coupled with an error in judgment, and an accident will occur. A careful survey of the record indicates that we have probably now come to the point where component reliability is so good that failure of a single component is seldom the sole determining factor in an accident. Most accidents are made up of some sequence of unusual events in the system as a whole, the system being the airplane, the pilot, the communications system, and the atmosphere. It is time to begin looking at the whole field of aircraft safety from the operations, or systems-analysis, point of view. If it is thoroughly studied in that frame of reference, I am sure that illuminating and beneficial results will be forthcoming which can permanently turn the curve of aircraft accidents downward again. Before this next half century is finished, I am sure that the motto of the Guggenheim Aviation Safety Center at Cornell University—"To make flying the safest form of transportation"—will be realized and, further, that reliability of service will be very close to complete satisfaction, at least better than 99 per cent. The details of such desirable improvements will, of course, encompass the improvement in capabilities and reliability of the many inanimate components of the transportation system. This will be particularly true of electronic devices. The greatest improvements here are being stimulated primarily by the military research and development program.

Volume of Traffic

In 1940, about 1 billion passenger-miles were flown by regularly scheduled commercial air liners in the United States. About this time, a number of capable, technical crystal-ball gazers got busy with analyses extrapolations, guesses, and hunches and began making

10-year predictions. Some of the more optimistic came out with the quite unacceptable forecast, as far as conservatives were concerned, that within a decade the amount of air travel would increase by 700 or 800 per cent. Actually, the performance turned out to be a bit better than these predictions.

Similar predictions, within the last 2 or 3 years, involving somewhat the same methods, have indicated that by 1960, the commercial air traffic should be approximately 15 billion passenger-miles—about double of that for the year 1950. Assuming a reasonably peaceful world and a period of economic stability, it strikes me that this is a safe prediction.

If one attempts to look further ahead than a decade or so by the use of analyses of past performance and extrapolations, he is in grave danger of falling heir to wishful thinking and simply playing his hunches. So if one is to look ahead for 5 decades, I think he might as well rely on guesses and hunches and let it go at that. On that basis, I am willing to volunteer an opinion that by the year 2003, the amount of commercial air traffic in the United States (including that now classed as executive-plane travel) will increase by tenfold over the present—namely, to the order of 100 billion passenger-miles—and that air cargo will have at least a corresponding proportional increase over the present. This would represent a substantial fraction (probably 10 per cent) of all forms of travel in the United States, and I would think it might very well represent a reasonably stable plateau.

The really marked increase in travel, however, will come in the international field, in which there is great room for beneficial expansion, not only because of the distances involved but because of the tremendous number of people who have never yet had the benefit of air travel. The population of the United States is less than 7 per cent of the population of the world and the remaining 93 per cent have as much basic appetite for goods and services as Americans have. If anyone is in the position of needing to give serious consideration to future international economic planning, it is my opinion he would be on safe ground to assume that 50 years from now the world air-travel picture will encompass at least 1 trillion passenger-miles per year. Although this will require a large number of airplanes, it will not be an astounding figure, certainly not more than a few tens of thousands of up-to-date aircraft to take care of all of the commercial transport for all parts of the globe.

The long-range military picture is so nebulous that one should probably not hazard any sort of a guess to pass on to the next generation. It is safe to say that the proportion of military activity handled by air will steadily increase, both for transport and combat duty. Whether the entire world will be heavily militarized in 50 years, whether we will be at peace or war or in a state of metastable equilibrium, is completely beyond anyone's powers to divine.

Finally, the extent of the use of the air will be determined by the amount of private flying. Here, much to the disgust of my aero-enthusiastic friends, I tend to remain on the pessimistic side. Basically, the business of flying with reasonable safety and reliability will, for the most part, be confined to the professionals, who have the best and most expensive equipment available, and this fairly well excludes the private flier with the light and inexpensive airplane. There will be more private light planes, and they will be used more than they are at the present, and the helicopter will have a significant role in this picture, but I cannot foresee enough of them to darken the sky or to serve as a substantial substitute for the automobile.

Perhaps I should attenuate this pessimism by stating that it is based primarily on patterns of economics rather than the laws of physics. If anyone wishes to alter the prediction, let him consider the following balance sheet.

What We Need in Everyman's Helicopter

An inexpensive, reliable machine, capable of foul-weather operation.

(A) Inexpensive—in the $4,000 to $5,000 price range.

(B) Reliable—safe to land with a power failure, which means several light, inexpensive engines.

(C) Foul-weather operation—a poor man's radar and autopilot, light and reliable.

What Must Be Done to Meet Need

(A) Develop reliable, light, inexpensive, highly efficient, jet-type, rotor-tip power plants which will be used two-to-three per blade.

(B) Develop the necessary inexpensive, lightweight reliable radar and autopilot gear. Here, as in many other items in the next 50 years, we might tread the path of victory through transistors.

(C) Thoroughly explore the entire private transportation systems of metropolitan centers to see where and how helicopters and automobiles can each fulfill their optimum roles.

A program to meet these needs for the private flier would take many years and many dollars. I would guess that 40 to 50 million dollars would make only a fair start on the required research and development. I do not visualize the aircraft industry putting that kind of money on a dark horse. Perhaps the automobile industry, which is primarily interested in mass transportation, will eventually desire to embark on such a program. If they do, it might possibly be successful, and I might have to eat my words of pessimism about the private helicopter. I would be very happy to do so.

The Astronaut

Undoubtedly it is a mark of advancing age, but you will observe from the preceding discourse that I have stayed on the conservative side of the predictions. At least I have made a poor showing in comparison to the comic strips and some fiction writers, and for this, to the more imaginative of my audience, I apologize. However, as a closing note, I would like to dispense

with the bonds of earth for a moment and look in on the astronaut of the year 2000 or so.

About 2 years ago, an experimental two-stage rocket rose to an altitude of 250 miles above the earth. Rocket velocities have been attained which are of the order of one-half of those required to put an object in a permanent orbit around the earth. The laws of physics have given us the nod, indicating that it is now possible—just barely—with available fuels and devices, to get a small fraction of the mass of a propulsive system to the velocities and distances that are demanded for space travel. Our developmental activities have taken us a substantial fraction, say one-fourth, of the way toward this accomplishment. The slick magazines have been well-filled recently with presumably serious expositions by Dr. von Braun and others dealing with the engineering and operational considerations of satellite vehicles, with extrapolated thoughts on space travel. Aeronautical engineers as a class, unless they happen also to belong to the American Rocket Society, tend to look askance at all such predictions and intimate that they wouldn't be caught dead even thinking about such things.

As is usually the case, the actual course of events will probably be somewhere in between the stands of the pessimists and the enthusiasts. Since the act of getting beyond the bounds of the atmosphere and the bonds of our gravity is physically possible, I feel confident that it will eventually be done, for the human race probably has a lease of at least a few more million years on this planet. Whether anything happens within the next 50 years or not depends primarily upon public interest and public support. The idea is so appealing, however, that I am confident that some attempts at the first aspects of space travel will be forthcoming within the next 5 decades, and I will predict that within that time there will almost certainly be a number of inanimate objects shot into appropriate position and with adequate velocity to follow an orbital path 1,000 miles or so above the earth, just to show that it can be done. Such exploratory missiles will also be used as instrument carriers to enlarge our knowledge of the physical makeup of the space adjacent to the earth. There is also a reasonable probability that someone will have sent an unmanned object to circumnavigate Miss Moon and photograph her back side.

I doubt that any person within this allotted period will have attempted a manned flight on either an orbital or free-space expedition, although undoubtedly many will be willing to try. If anyone does attempt it, I think it will be premature, and the volunteer will not return to the earth alive. Eventually there will be successful manned flight into space, but I do not visualize it as an activity of the next 5 decades. As to ultimate possibilities, I find it hard to visualize them beyond the local scene—to the distance of the moon or thereabouts. The estimates of the probability of visiting or circumnavigating the other planets of the solar system I leave to some future predictor, and I do not believe he will have enough sound evidence at hand within the 20th Century to make valid forecasts of success.

To keep the discussion within bounds, I should state that I am certain that, in the realm of space travel, no human being will ever have the privilege of going beyond the bounds of the solar system. Even if physics and engineering permitted it, the limitations of life span and physical needs would put it in the realm of the impossible for genus Homo. This gloomy pall of reality should not, however, prevent any boy from retaining Buck Rogers as a congenial fireside hero.

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The Birth of an Engine*

British Practice in Aviation Engine Procurement and Development

F. R. BANKS†

Ministry of Supply, Great Britain

Introduction

I have been asked to describe the methods used in Great Britain whereby engines are born and brought to manhood—if not to maturity—since all aviation engines are subject to a continual refining and revitalizing process. I propose, therefore, to describe the procurement or contractual methods at present used by the Ministry of Supply to obtain aviation engines and, also, to give my views on engine development.

Ministry Procurement or Contractual Procedure

The essence of any satisfactory procedure is the speed and simplicity by which it can be implemented; and this, in turn, will depend upon the degree of mutual trust there is between the Industry and the Government Department concerned. I am not being at all complacent when I say that the British methods of initiating and progressing an engine contract are the most satisfactory I have yet encountered for rapid action and comparative freedom from official "bumbledom" and paper work, giving the engine manufacturer full scope to go ahead and do his best in evolving a new engine.

There is no formal method of determing a requirement for a new engine. Such a need may stem from a specific aircraft project, resulting from an Air Staff "operational requirement," for which existing engines are unsuitable; it may originate within the Ministry of Supply or from an engine manufacturer, ahead of a specific aircraft requirement, or come as the result of discussions between the latter and an aircraft constructor whose new project—it is mutually hoped—may be of such merit as to warrant an Air Staff requirement being written around it.

Recently, an attempt has been made to assess more accurately the right size and type of engine to build in anticipation of a future aircraft requirement so that it may have some chance of being developed to an acceptable standard and well in advance of the prototype aircraft.

In this instance, meetings were held at the Ministry with the aircraft designers of both fighters and bombers (in two separate groups). As a result of these informal discussions, which considered hypothetical, but probable, aircraft requirements in each case, it was possible to get some idea of the "envelope" or parameter of maximum power and performance required and whether this power should be vested in one or two engines for the fighter or, say, more than four for the bomber.

After some idea of the likely power and performance required from a single engine was obtained, visits were then made to the engine firms to discuss informally which of a number of design suggestions might best meet the (hypothetical) aircraft need. The meetings to date have led to the preparation of some interesting general

* Dinner Speech, Eighth Annual Flight Propulsion Meeting, IAS, Cleveland, March 13, 1953.

† Air Commodore F. R. Banks has been lent by The Associated Ethyl Company Ltd., to be Principal Director of Engine Research and Development, Ministry of Supply, London, England.

arrangement drawings and design brochures by the engine companies, which are now being studied.

My reason for stressing the importance of coming to the earliest possible decision for a new engine is that its gestation period of 4 or 5 years, from the commencement of design to the Type Test stage, rarely gives sufficient time to get the engine ready for the prototype aircraft, and there is often far too little background of bench and flight testing.

Also, since the turbojet and its aircraft are so interdependent, to meet the designed performance—and it is not possible to consider one without the other—an engine that is already available is a safer bet than one which is only a gleam in the designer's eye when the aircraft requirement is already established.

The obvious risk in building an engine much in advance of a specific aircraft requirement is that it may not be wanted immediately, to the discouragement of the engine manufacturer; but this is where experience and a nice sense of judgment and timing come into the picture, coupled with an attractive engine, which, like a woman, cannot be refused or ignored.

The Nene (J.42) was in exactly this position when it was built. We ordered it, thinking at the time (1944) that an engine of 4,000–5,000 lbs. thrust would be required; but no aircraft became available for a year or two afterward until the Hawker N.7 (the prototype of the Sea Hawk) was designed for it.

For that matter, the Avon, Ghost and Sapphire engines were ordered against no specific aircraft requirement; and, though the Dart and Mamba propeller turbines were originally ordered for an RAF trainer, they were never actually used for this purpose but have since been fitted to quite different aircraft—the Vickers Viscount (Dart) air liner and the Fairey Gannet (Mamba) naval aircraft.

The early idea that the gas turbine could be tailored for each aircraft requirement has not been realized in practice; and the situation today is similar to that of the piston-engine era, where the engine took longer than the aircraft to develop and the latter was generally tailored to suit.

What gave rise to the "tailoring" theory was the relative simplicity and consequent ease of manufacture of the Whittle-type engine and the fact that this new prime mover demanded close matching with the aircraft. But, since the axial-compressor-type engine has now come into its own and is so prodigal of man-hours to manufacture, it would be most expensive to build a plurality of different engines to suit each and every new type of aircraft.

I will now summarize the Ministry of Supply procedure for engine procurement as follows:

(1) If the idea for an engine originates from the Ministry of Supply, it is discussed with a number of engine firms, particularly those having the most experience of the particular engine type. If, however, the project comes from one firm, then discussions are held with that firm alone.

(2) When ideas have been sufficiently crystallized to produce a general arrangement drawing and design brochure, the National Gas Turbine Establishment may be brought in for a technical assessment of the design. (This is an aero- and thermodynamic assessment, but, sometimes, comment is also requested upon the mechanical design.) The Ministry of Supply and the Royal Aircraft Establishment aircraft projects sections will also be asked for an appreciation of its performance suitability for a foreseeable aircraft requirement.

(3) There is no fixed rule that a firm aircraft requirement is necessary before an engine can be ordered. Conversely, some aircraft projects of radical or unconventional design may demand entirely new or considerably modified engines, which must then be ordered in parallel with the prototype aircraft.

(4) The Principal Director of Engine Research and Development, having satisfied himself that a particular engine should be ordered, will decide which of the firms submitting brochures should be given the contract, assuming the project is not the idea of any one firm. He will take into account the engine type and determine the firm or firms most capable of executing the final design and bringing the development of the engine to fruition. Often, a contract will be awarded to more than one engine firm, particularly if the requirement and conditions are sufficiently unusual or novel to warrant some insurance measure and spreading of the technical risk. Consideration will also be given to the pressure of work at each firm and the overall loading of the Industry.

(5) Having made his decision, the Principal Director of Engine Research and Development will submit a formal request for the engine to the Controller of Supplies (Air) through the Director-General of Technical Development (Air) and, in some cases, the Principal Director of Scientific Research (Air). (See Fig. 1.) Upon receiving agreement, a requisition is then submitted to the finance (Air 2) and contract branches for financial approval and contract action to order a number of development engines. Since the War, six engines have usually been ordered, but this number may be increased as development proceeds and, particularly, when the experimental flight stage is foreseen.

(6) Before the finance branch clears the requisition, it must first seek Treasury approval. This applies to a completely new engine type rather than to another "Mark" of an existing engine, the expenditure for which can usually be approved directly by the finance branch within the Ministry.

The Development Engine Supply Contract issued to the firm may or may not be linked in the first place with a detailed specification for the engine. This will depend somewhat upon the stage reached in the design of the engine and when the contract is received. The design may have progressed so far as to permit a complete specification to be written, or, if the discussions prior to contract action have been brief, the contract may then refer to "a specification to be issued

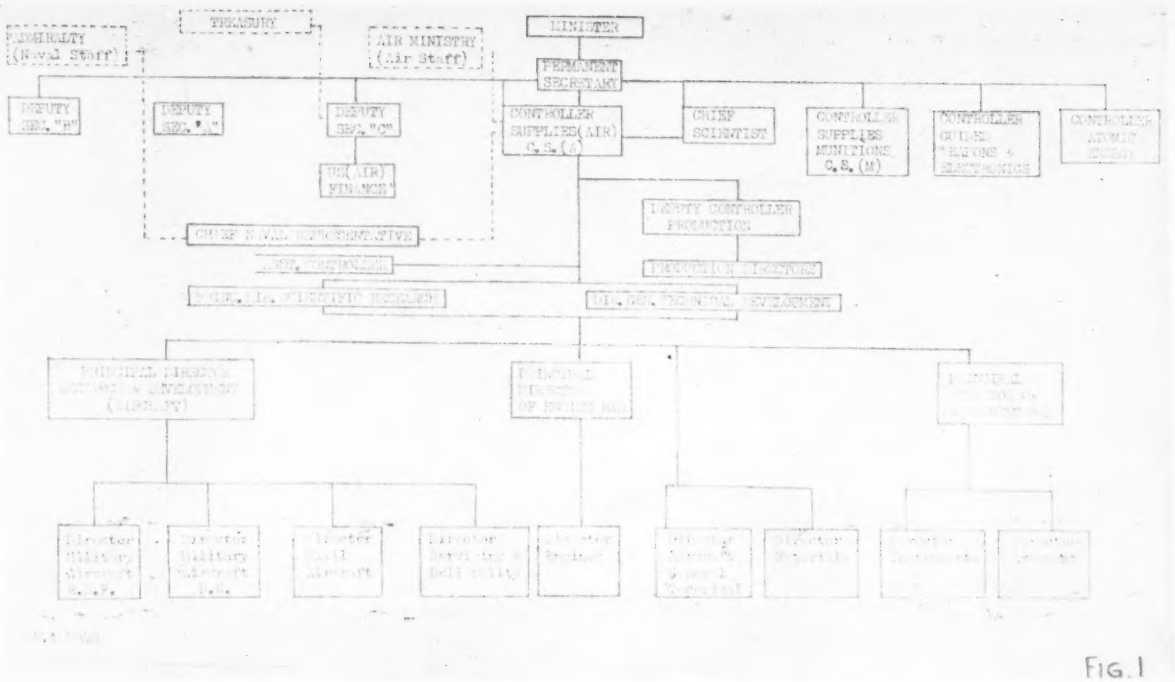

FIG. 1

later." Specifications 2100 and 2300, which detail the common requirements for aviation turbine engines, must be adhered to as a contract requirement.

The whole contractual procedure, from the time it is agreed to order the engine, may take from 1 to 3 months to complete; but this does not normally delay or restrict the engine manufacturer, who will go ahead with his final design. If absolutely necessary, an "Instruction to Proceed" can be issued pending completion of the contract action.

The Ministry do not pay separately for the design of of an engine, but the cost of this will be included in the engine supply contract.

The whole contractual procedure is flexible and greatly depends upon the goodwill existing between the Ministry and the engine contractor.

When a contract is awarded to a firm, it will usually confirm the manufacturer's tender and price for designing the engine and building a number of prototypes for bench development. This initial contract may also include any additional engines that have been agreed upon between the firm and Ministry for a flying test bed or any aircraft prototypes calling for the engine.

As a general rule, the engine manufacturer will initially require about six engines for bench tests, with two or three additional engines, later, for his experimental flight tests. The number required for each prototype aircraft will depend upon the type of aircraft and the number of engines fitted. In the case of multiengined aircraft, it is usual to estimate spare engines on the basis of 50 per cent of the number of engines fitted in the aircraft—i.e., four plus two for a four-engined machine. For a single engine fighter, the quantity of engines ordered will depend upon the number of aircraft ordered off the prototype, but it is usually kept to about 50 per cent of the engines fitted—the minimum spares being one, for one or two aircraft only.

It is unlikely that the manufacturer will machine more than two or three complete sets of engine parts at the outset, leaving the remainder in the form of rough forgings and castings, etc., since a radical change and complete redesign may become necessary as the result of failure in the early development phase.

The contract price and conditions for these engines will make provision for an acceptance test of the prototype engines, at powers to be decided later. The conditions of the acceptance test for the first prototype engine will depend upon the type of engine and whether its design follows well-tried lines (such as another Mark of an existing engine) or whether it is entirely original. In the former case, the test conditions may demand a 2 hours' run on the test bed at a high percentage of the engine's maximum rating. If the engine is of original design or represents completely new practice, the test will only be a nominal one consisting of about 2 hours at, say, 50 per cent power. In practice, the conditions of the acceptance test are flexible and are dictated by past experience and the knowledge of the engine submitted for test.

The original purpose of the test was to ensure that an engine was up to a certain technical standard to justify the expenditure of public funds upon its further development for eventual adoption as a Service type. In actual practice, however, the acceptance test is regarded merely as practical proof of completion of the initial prototype engine and that it is capable of running. It is felt impracticable to expect a completely new engine to pass more than a nominal test; other-

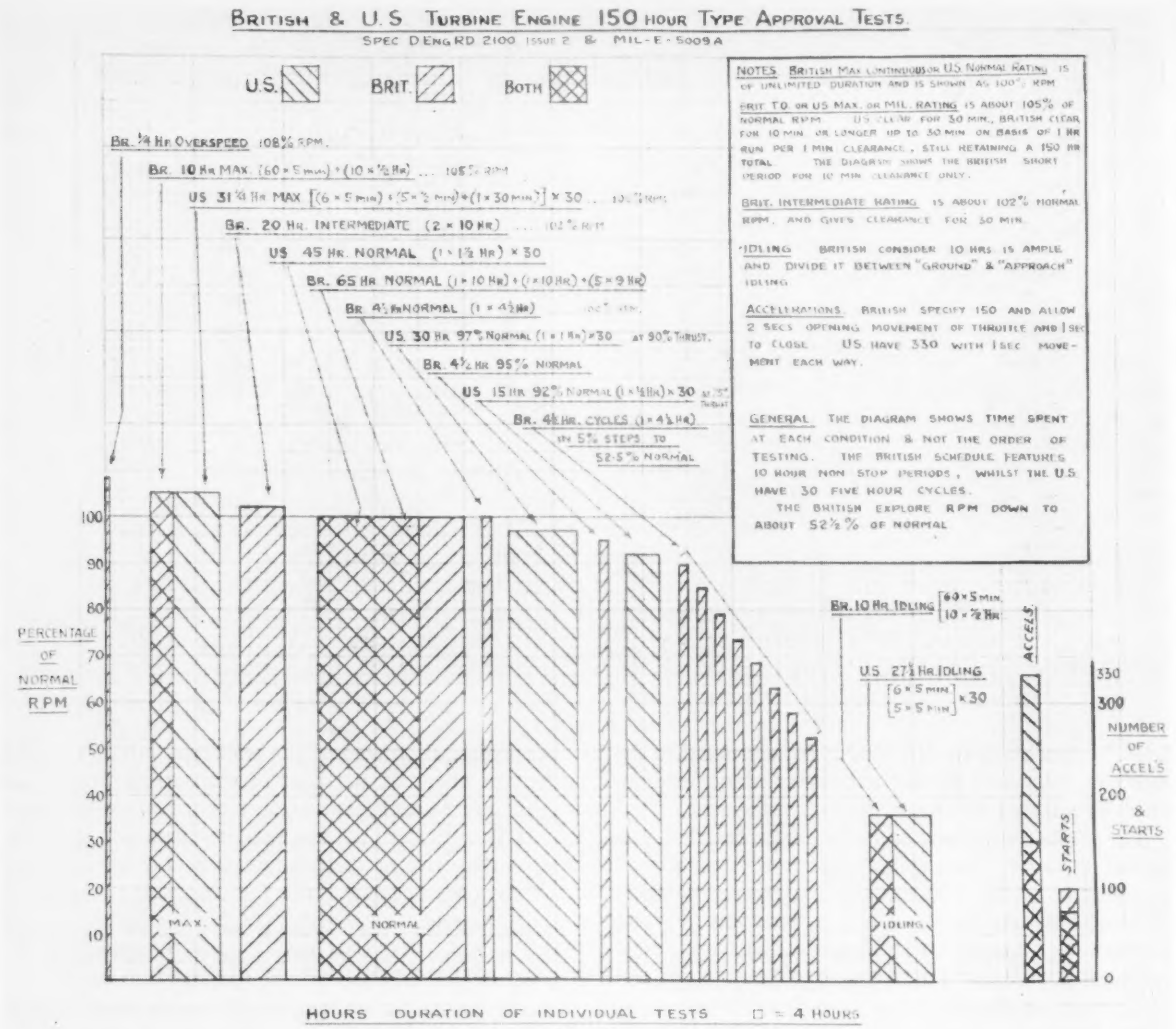
BRITISH & U.S TURBINE ENGINE 150 HOUR TYPE APPROVAL TESTS.
SPEC D.ENG.RD 2100 ISSUE 2 & MIL-E-5009A
U.S.
BRIT.
BOTH
BR. ½ HR OVERSPEED 108% RPM.
BR. 10 HR MAX. (60×5 min)+(10×½ HR) ... 105% RPM
US 31½ HR MAX [(6×5 min)+(5×½ min)+(1×30 min)]×30 ...
BR. 20 HR. INTERMEDIATE (2×10 HR) ... 102% RPM
US 45 HR. NORMAL (1×1½ HR)×30
BR. 65 HR NORMAL (1×10 HR)+(1×10 HR)+(5×9 HR)
BR. 4½ HR NORMAL (1×4½ HR)
US. 30 HR 97% NORMAL (1×1 HR)×30 AT 90% THRUST.
BR. 4½ HR 95% NORMAL
US 15 HR 92½% NORMAL (1×½ HR)×30 AT 75% THRUST
BR. 4½ HR. CYCLES (1×4½ HR) IN 5% STEPS TO 52·5% NORMAL
NOTES BRITISH MAX CONTINUOUS OR U.S NORMAL RATING IS OF UNLIMITED DURATION AND IS SHOWN AS 100% RPM
BRIT TO OR US MAX. OR MIL. RATING IS ABOUT 105% OF NORMAL RPM. ... U.S. CLEAR FOR 30 MIN., BRITISH CLEAR FOR 10 MIN. OR LONGER UP TO 30 MIN ON BASIS OF 1 HR RUN PER 1 MIN CLEARANCE, STILL RETAINING A 150 HR TOTAL. THE DIAGRAM SHOWS THE BRITISH SHORT PERIOD FOR 10 MIN CLEARANCE ONLY.
BRIT. INTERMEDIATE RATING IS ABOUT 102% NORMAL RPM. AND GIVES CLEARANCE FOR 30 MIN.
IDLING BRITISH CONSIDER 10 HRS IS AMPLE AND DIVIDE IT BETWEEN "GROUND" & "APPROACH" IDLING
ACCELERATIONS. BRITISH SPECIFY 150 AND ALLOW 2 SECS OPENING MOVEMENT OF THROTTLE AND 1 SEC TO CLOSE. US HAVE 330 WITH 1 SEC MOVEMENT EACH WAY.
GENERAL THE DIAGRAM SHOWS TIME SPENT AT EACH CONDITION & NOT THE ORDER OF TESTING. THE BRITISH SCHEDULE FEATURES 10 HOUR NON STOP PERIODS, WHILST THE U.S. HAVE 30 FIVE HOUR CYCLES.
THE BRITISH EXPLORE R.P.M DOWN TO ABOUT 52½% OF NORMAL
PERCENTAGE OF NORMAL R.P.M
100
90
80
70
60
50
40
30
20
10
MAX.
NORMAL
IDLING
BR. 10 HR IDLING [60×5 MIN / 10×½ HR]
US 27½ HR IDLING [6×5 MIN / 5×5 MIN] ×30
ACCELS
STARTS
330
300
200
100
0
NUMBER OF ACCEL'S & STARTS
HOURS DURATION OF INDIVIDUAL TESTS □ = 4 HOURS

FIG. 2

wise, costly development would devolve upon the engine contractor who would, in these days, find difficulty in bearing it. Each and every prototype engine must, however, pass an acceptance test, the severity of which is increased progressively according to the state of development and behavior of the engine or engines previously built, until a firm rating has been established for the type. Engines accepted subsequently must then pass a 2-hour test based on this rating. The object here is to achieve a better standard for each subsequent engine.

After the acceptance test and when the engine has been stripped and examined by Ministry inspectors and those of the firm, bench running is commenced on another (separate) contract calling for x hours of experimental running at the rate of £y per hour.

British practice is to issue one contract for building the prototype engine(s) and another for its development (experimental running). The latter can be extended or a fresh contract granted as development proceeds. Normally, the firm will allow in their estimates for the replacement of failed parts and also the design and manufacture of any new components needed during the development of the engine; but a radical redesign for, say, an increased performance requirement will be covered by another contract.

A Special Category or flight clearance test, similar to your USAF Flight Substantiation Test, is required before the engine can commence experimental flying. This is usually a test of 25 hours' duration but may involve a longer period depending upon the state of development of the engine at the time. If, for example, the engine has had 2,000–3,000 hours of bench running, including some 150-hour periods, then a 25-hour test may be adequate to clear it for flight; but, if relatively little bench testing has been accomplished or if the total running time is composed of short runs, a longer test may be demanded. The full brochure rating of the engine may not necessarily be demanded if early flight testing is considered desirable.

At what particular stage of development this test is done will depend entirely upon the progress made and

when the engines are required for the prototype aircraft; but it is usually completed as soon as practicable to establish the engine's performance and potential reliability. Where possible, a flying test bed is also provided to establish the performance and handling characteristics of the engine and its reliability in flight.

We regard the experimental flying phase of a new engine's development as equal in importance and complementary to bench testing, and there is now in draft form, but not yet approved, a "Flight Test Schedule." The object of this new schedule is to regularize and standardize flight testing procedure where possible, which, to date, has been rather left in the hands of the individual engine builder to work out in his own way.

Finally, comes the Type or Model Test of 150 hours' duration. The engine manufacturer will try to complete this test as soon as he is satisfied that the performance and mechanical standard of the engine justify the attempt. The official Type Test is usually preceded by a number of 150-hour tests, which are run to Type Test conditions but not subject to official observation and measurement of dimensions before and after test.

I have shown graphically, in Fig. 2, the differences between British and United States Type and Model Tests. British official engine tests are done at the plants of the engine manufacturers and not at government establishments but are under Ministry supervision. All engine performances are brought to standard sea-level conditions by officially approved correction factors. We consider that our Type Test fairly closely represents actual engine flight conditions, as evidenced by the performance of the Ghost engine in the Comet and the Avon in the Canberra.

Normally, the completion of the Type Test permits the sealing of the Drawing Introduction Sheet (a list of approved drawings for that engine type or model), which act of approval allows production to proceed. But, if it is urgently required to put the engine into production, permission can be given to release material and tooling in advance of the Type Test; separate sections of the Drawing Introduction Sheet may also be approved and sealed before the Type Test, to enable machining of components to commence. An Instruction to Proceed can also be issued for speeding production preparations as for expediting development engines.

After the Drawing Introduction Sheet is sealed (or any of its sections), prior agreement of the Engine Modifications Committee (EMC), at the Ministry, is required before any further design changes are made. Until the Drawing Introduction Sheet is sealed, design changes are largely the firm's concern.

There is also the Local Modifications Committee (LMC), which operates at the firm under the chairmanship of the Resident Technical Officer. The members of this Committee are drawn from the firm, the Resident Technical Officer's staff and the Aeronautical Inspection Directorate.

Where possible, the LMC puts forward to the EMC modification proposals for the latter's approval. If approval is obtained, the LMC decides the tests required and, upon their successful completion, prepares a case for the final approval of the modification by the EMC. This will include the cost of introducing the modification and the estimated date for putting it into production, etc. During the last war, modification action was, in certain cases, speeded up by giving more authority to the LMC.

The Services, the Royal Navy and the Royal Air Force, are also represented on the main (EMC) committee.

All these proceedings are exceedingly flexible and can be expedited if necessary. For instance, if the matter is urgent, the Resident Technical Officer at the particular firm may 'phone the Chief Resident Technical Officer at the Ministry, who will then speak with the members of the EMC and clear the modification required to the Resident Technical Officer. The paper work is then put in order at the next EMC meeting.

British procedure for the performance acceptance of production engines is as follows: First, the brochure performance is vetted by the Ministry and, if accepted as the performance likely to be achieved, the Type Test conditions for the engine are then based upon a combination of r.p.m. and jet-pipe temperature calculated to give as nearly as possible the brochure power. Production engines are expected to meet this performance but are allowed a low limit of 4 per cent below Type Test power to pass, provided the jet-pipe temperature is within the permissible limits. As I understand it, United States practice is to declare the nominal maximum engine rating as the minimum acceptable for clearing production engines.

In our view, there is little to choose between the two procedures, but, at present, we favor our own method. We always attempt to obtain, from Type Test results, a nominal rating that will represent the average production engine; and we have also found, in practice, that the average negative tolerance on production test is nearer 2 than 4 per cent. There is little advantage, and sometimes considerable disadvantage, in erring on the high side of jet-engine performance in production because of the effect it may have upon fuel consumption and range. In the case of multiengined aircraft, it is important that the average hourly fuel consumption is not substantially different from the nominal figures supplied to the aircraft designer. For the single-engined fighter, a wide variation in thrust or fuel consumption between production engines can also be embarrassing.

A reduction in the negative allowance, from 4 to 2 per cent, while still retaining the present nominal average rating, may soon be agreed. In this connection, we have successfully tried, in certain cases, the United States method of adjusting propelling nozzle areas by means of trimmers or "mice."

Another allowance is also made in the Type Test to meet engine behavior at altitude. At present, British

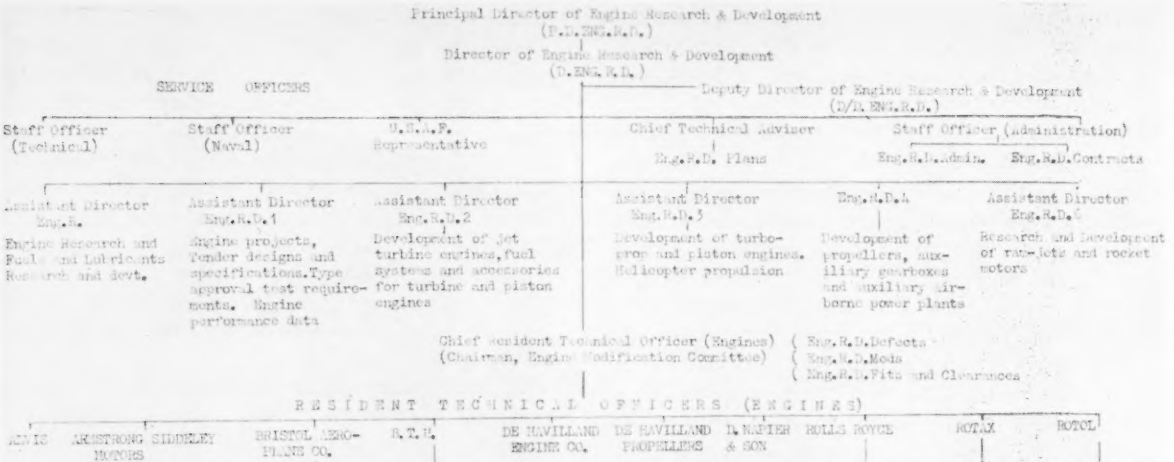
Principal Director of Engine Research & Development (P.D.ENG.R.D.)
Director of Engine Research & Development (D.ENG.R.D.)
SERVICE OFFICERS
Deputy Director of Engine Research & Development (D/D.ENG.R.D.)
Staff Officer (Technical)
Staff Officer (Naval)
U.S.A.F. Representative
Chief Technical Adviser Eng.R.D. Plans
Staff Officer (Administration)
Eng.R.D.Admin.
Eng.R.D.Contracts
Assistant Director Eng.R.D.1
Engine projects, Tender designs and specifications. Type approval test requirements. Engine performance data
Assistant Director Eng.R.D.2
Development of jet turbine engines, fuel systems and accessories for turbine and piston engines
Assistant Director Eng.R.D.3
Development of turbo-prop and piston engines. Helicopter propulsion
Eng.R.D.4
Development of propellers, auxiliary gearboxes and auxiliary airborne power plants
Assistant Director Eng.R.D.5
Research and Development of ram-jets and rocket motors
Chief Resident Technical Officer (Engines) (Chairman, Engine Modification Committee)
Eng.R.D.Defects
Eng.R.D.Mods
Eng.R.D.Fits and Clearances
RESIDENT TECHNICAL OFFICERS (ENGINES)
ARMSTRONG SIDDELEY MOTORS
(Visiting Technical Officer to:-
METRO-VICKERS & BROCKWORTH ENGINEERING CO.
BRISTOL AERO-PLANE CO.
(Visiting Technical Officer to:
A.C.F. (Trefforest)
R.T.D.
(Visiting Technical Officer to:
JOSEPH LUCAS
H.M. HOBSON
S.U. CARBS.
LODGE PLUGS
AMAL
AUTOMOTIVE PRODUCTS
ELECTRO HYDRAULICS
DE HAVILLAND ENGINE CO.
DE HAVILLAND PROPELLERS
D. NAPIER & SON
ROLLS ROYCE
(Visiting Technical Officer to
STANDARD MOTORS
ROTAX
(Visiting Technical Officer to:
ULTRA ELECTRIC & SIMMS MOTOR UNIT
ROTOL
(Visiting Technical Officer to:
BOOTY FUEL SYSTEMS
TOTAL PERSONNEL IN DIRECTORATE AND OUTSTATIONS (SCIENTIFIC, ENGINEERING & CLERICAL) = 144

FIG. 3

engines employ a method of control in which the fuel supply is regulated by throttle setting and ram pressure, with a top limit controlled by a maximum speed (r.p.m.) governor but without any link-up with jet-pipe temperature. Since jet-pipe temperature often tends to increase with altitude, it is necessary to set the limiting temperature, for acceptance of the engine, at 20–30° C. (36–54° F.) below the operating limit fixed by the Type Test to meet this temperature increase, although the minimum acceptable thrust must remain within the 4 per cent drop allowed for production engines.

Automatic jet-pipe temperature control is now being developed and will be introduced on all British engines in the near future. This will relieve the pilot of continually having to adjust the throttle to avoid exceeding engine temperature limitations.

The reason for accepting production engines at a lower jet-pipe temperature than that cleared on Type Test is not only to cover the altitude case but also to meet the sea-level tropical condition of high inlet temperature. Often, Type Tests are run with smaller than standard final nozzle area to clear for high temperature, which procedure incidentally gives higher than brochure thrust.

Insofar as reliability is concerned, the test-bed thrust is secondary in importance to r.p.m. and turbine inlet temperature. But, taking the case of the propeller turbine, we *are* interested in the actual shaft horsepower developed on account of reduction gear and propeller stressing.

The Type Test (plus previous development running) determines the operating limits of r.p.m. and temperature and, therefore, only a preliminary or provisional power rating is given the engine upon completion of this test. The thrust of a turbojet (or the horsepower of a propeller turbine) is finally based on the average performance of a number (10–20) of production engines. This might even lead to an increased rating, within the acceptance limits of r.p.m. and jet-pipe temperature established on Type Test.

The acceptance test for production engines is fully described in Specification 2100. Briefly, this consists of an endurance test, a strip examination and final test. The former demands two starts, one of which must be from cold (ambient temperature), by the starter motor that will be fitted to the engine in service. There is then some preliminary running to show that the engine is operating satisfactorily. After this, the engine is given 5 min. running at ground-idling r.p.m. followed by 1 hour and 50 min. at maximum continuous r.p.m. and 10 min. at the maximum declared r.p.m.

Next come three accelerations from ground-idling r.p.m. and three from approach-idling r.p.m., to take-off thrust or power. The time taken to move the control lever from approach idling to the take-off position must not exceed 2 sec., and the time for the engine to accelerate from approach-idling r.p.m. to 95 per cent of take-off thrust or power must not exceed 5 sec., unless otherwise agreed.

Six decelerations from take-off to ground-idling conditions are then specified, and the time taken to move the control lever from take-off to ground-idling position must not exceed 1 sec.

After production test, the engine is then completely stripped for examination. If in satisfactory condition, it is reassembled and run to a schedule given under the heading "Final Test" on page 25 of Specification 2100.

The top officials of the engine branch at the Ministry attend regular technical meetings at the firms to discuss the progress of each contract item. Decisions can then be reached and action taken with the minimum delay, keeping all concerned informed of a particular engine's state of development and the progress of any engines programed for prototype aircraft, etc. These meetings, which were held at monthly intervals during the last war, are now scheduled for every 6 weeks.

Naturally, the development of an engine continues after the Type Test for design refinement and to increase the power rating or to improve the fuel consumption, to lengthen its life between maintenance periods, and for the investigation of defects resulting from actual use in military service.

Incidentally, all engines for prototype aircraft are included in the Research and Development budget and are not debited to Production. This system has one disadvantage where limited funds are concerned: the successful engine firm, whose engines have been accepted for a number of different prototype aircraft, must allow for the absorption of a relatively high proportion of research and development expenditure in the manufacture and supply of these preproduction engines. This method of procurement is, however, advisable since it is essential to have full technical control of all engines in their experimental flight stages.

It should be stated here that all engine-driven accessories, which include those necessary for the functioning of the engine (fuel and oil pumps and starters, etc.) and those driven by the engine for the aircraft services, must pass the engine Type Test. They are also subjected to many hundreds, and even thousands, of hours of experimental and endurance running on rigs.

Fig. 3 is the organization chart of my Directorate in the Ministry of Supply. It is, I hope, self-explanatory, but I would draw your attention to the footnote, which gives the total number of personnel employed—i.e. 144. This includes the scientific, technical and clerical staff at headquarters and at the engine firms.

Since the man and not the machine is the controlling factor in the creation of an engine (or anything else for that matter), the question of personnel is of the first importance, and the exercise of benevolent control by a minimum of Ministry staff is only possible if experienced individuals are available.

Practically all the technical and scientific staff members in the aircraft and engine Directorates of the Ministry of Supply are civil servants, although there is a sprinkling of Service officers heading up some of the Directorates and sections. I have Royal Navy and RAF officers on my staff, whose duties are to supplement our normal contacts with the Services and to keep in touch with their respective Services regarding behavior of the equipment in the field. This group also includes a USAF officer who is attached to my Directorate on the exchange basis now operating between Britain and the United States.

I favor a hard core and a high proportion of civilian technical personnel in these Directorates, since their individual and aggregate experience is considerable and they are able to guide and advise any officer personnel who may head a Directorate from time to time but whose tour of duty (usually 3 years) is hardly sufficient, without some previous background of experience, to permit the exercise of balanced judgment without such advice.

I do not believe in putting civil servants in uniform and, therefore, rendering them subject or subservient to military law and discipline, except for their own protection in a theater of war.

With regard to the relationship between the Ministry and Industry, I always try to impress upon my staff that we do *not* build the engines but are there to help the Industry and see that we get what we want, and, while we can give advice to a firm on a particular technical point, it is for the latter to seek its own design and mechanical solutions. But we have, both at the Ministry and the National Gas Turbine Establishment, experienced performance specialists and engineers who can advise critically on engine design and development and whose opinions and advice are always in demand by the Industry.

Engine Development

I have tried to explain, as briefly as I can, the contractual procedure operated by the Ministry of Supply and the relationship between the Ministry and the Industry in the procurement of aviation engines. But, while these play leading roles in the birth of an engine, the most important part, the actual birth, takes place at the manufacturer's plant.

It is not an overstatement to say that there are only a few firms in the world today who really understand the art of developing and building a successful aviation engine and who can carry the whole effort through effectively and expeditiously. The aviation engine still represents an engineering art, even in this fiftieth year of its first successful venture into the air, an art aided by modern science and technology.

While the aviation gas turbine is taking the place of the piston engine for most, if not all, important aircraft applications, and responds more readily than the latter to theoretical treatment in the design stages and prior to prototype manufacture, it was not until it got into the hands of the legitimate aviation engine manufacturer that it really progressed. In fact, it is because of the accumulated experience of the aviation piston engine in the last 30 years that the gas turbine has progressed so rapidly.

The industrial engineering firms were the first to be introduced to the aviation gas turbine because they alone had any sort of turbine experience, which was thought (wrongly) to be needed for this engine's successful future development. The War and their own prejudices prevented or delayed the acceptance of this new prime mover by the legitimate aviation-engine builders. The industrial firms did, however, make one or two good attempts to design and build a workable

turbojet engine. These concerns, with many years' experience in the manufacture of massive steam turbines and electrical generating plants for public utility purposes and for ship propulsion, could hardly be expected, almost overnight, to get down to such a lightweight piece of mechanism as the aviation engine. Their past experience was all in the design of engines having safety factors that permitted 20 years of trouble-free operation. Since little or no restriction was placed upon the weight of such plant, it was not necessary to obtain the absolute maximum output or to reduce scantlings. Indeed, it would have been quite uneconomic to do so.

These conditions have always governed and enforced conservative practices in the industrial field, and it is surprising to me that any progress was made at all with the aviation gas turbine by the industrial engine firms. But, in my opinion, it will take another 10 years for those industrial organizations remaining in this specialized business to master the design technique and development of the aviation engine and then only if they are willing to learn by bitter experience. And where will the *successful* aviation-engine firms have progressed by that time? I emphasize the word "successful" since some of the legitimates in the aviation engine industry have "fallen flat on their faces" and nearly to ruin as a result of lack of a sound engineering policy and good technical control, or being overridden by bankers and accountants who came in at the top because of previous bad management and then tried to dictate technical policy.

Take heed! While these gentlemen are necessary for the proper support and operation of any and every engineering concern, do not allow them to dictate technical policy or override those whose business it is to control such policy.

I have already inferred that aviation engineering is quite peculiar and different from any other class of engineering, particularly since it must always carry such a large research and development load relative to that of production. I have long come to the conclusion that aviation, as such, is more a state of mind than anything else. If you wish to progress in this field you must think aviation, breath aviation and live aviation. Your family will first be enthusiastic in their association with this great something that is aviation. Then, as you finally become completely absorbed, they will become resentful, angry and even violent, or just resigned, leaving you to it and going off on their own and finding a hobby or pursuit as far removed from aviation as possible. Be that as it may, unless you absorb aviation into your very soul, you will never have the enthusiasm to beat your brains out in trying to solve the insuperable problems that arise from minute-to-minute, hour-to-hour, day-to-day, year-to-year and decade-to-decade.

To be first in producing good engines it is essential that you be enthusiastic. Then you must create an organization that can make, break, and remake and, finally, produce engines more quickly than your competitors. The ability to "make and break" engines rapidly and to keep a flow of experimental engines which practically swamps the test benches is the only known way of successfully developing an aviation engine.

Assuming careful and competent design in the first place, bench running and flight testing are the cheapest form of engine development. It is when the engine is off the test bed and lying in the shops, waiting for new or modified parts, that time and money run away. One can usually single out a successful firm by the number of engines you see or hear on test during a year of visits. In the case of the less successful concern the silence in this respect can sometimes be deathly—to the firm. I emphasize the great importance of sound design, since 1 month spent in the design office can save many months of prolonged development afterwards.

Contrary to our optimistic prognostications of 6 or 8 years ago, when it was thought that the turbojet could be designed, built and type-tested within 2 years, the modern axial engine takes about the same time to bring to the Type Test stage as did the larger and more complex piston engine. But the gas turbine, whatever its type, passes through the flight test stages and into actual service much more quickly than the piston engine, principally because of the considerably reduced mechanical and installational problems and the, almost, complete lack of cooling requirements. The day-to-day inspection and maintenance of the gas turbine in military and in air-line service absorbs far less man-hours than does piston-engine inspection.

These desirable features of the gas turbine have permitted some modification of past practice with regard to the procurement of engines for civil use. In the period between the last two wars, the high-duty piston engine generally originated as the result of a military requirement and was afterwards adapted to civil needs. Therefore, its basic teething troubles were largely overcome before being put to air-line use, although civil operation always brought out other weaknesses not apparent in military service, principally because of engine hours accumulating more rapidly and the air-line operators' demand for longer running time between maintenance periods. Since the last war, however, military requirements have not always included the particular engine types wanted for air-line operation, and, in certain cases, it has been necessary to design and build such engines (propeller turbines) specifically for civil purposes. This has meant the introduction of engines having no previous flight background, the accumulation of which then falls upon the aircraft manufacturer and the air-line operator. It is, therefore, fortunate that the gas turbine lends itself better to more rapid flight development and acceptance than the piston engine.

Turning now to the rate of engine development: the design of an axial-type turbojet of 8,000–10,000 lbs. static thrust absorbs about 1 year, and a further 12 months or more will be required to build the first prototype engine—or, say, 2 years from the first line on the drawing board to the test bench, ready to run. Then,

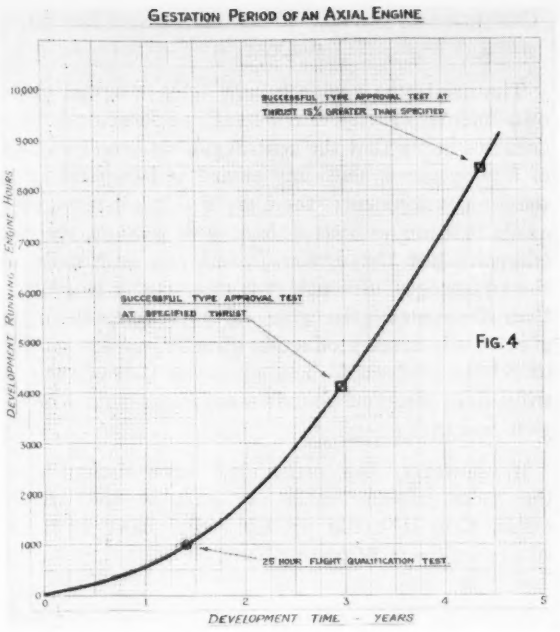

FIG. 4

in the following 3 years, there should be completed 8,000–10,000 engine hours of bench running and about 2,000 hours of flight testing. From 3,000–4,000 engine hours of bench running is a good yearly figure in the fourth and fifth years. In Fig. 4 is shown a curve giving the average period for developing an axial engine from commencement of design to Type Test.

Personally, I used to think that when we had built a number of axial engines we would be able to see a reduction in this 4- or 5-year period because of our greater accumulated knowledge of the axial compressor. But there are yet a number of problems to be mastered, and we still meet the same old troubles of compressor stall and blade vibration and "flutter," in addition to which any new engine represents an advance that will bring with it different conditions and other unknowns. We are, however, in a better position to overcome these troubles more quickly than was the case a few years ago.

In my opinion, there is one important difference between British and American practice as affecting the rapidity of prototype engine manufacture. We still have some good trade or craft apprentice schemes in our engine firms which produce skilled workmen (fitters and machinists), with the result that experimental engines can be built relatively quickly and with the minimum of jigging and tooling. Admittedly, we are presently short of skilled labor. This is due to the fact that the state of our national economy is such that there has been an almost barometric variation in the orders given to the aircraft industry, according to the state of world politics: labor, particularly, is chary of an industry that appears to prosper only in time of war or national emergency and would rather remain in the more stable industries whose operations are relatively steady or less subject to violent change.

We also lack a sufficient number of highly qualified men coming from our universities and technical colleges and are already feeling this deficiency.

However, we do appear to have a more stable condition in our design offices. I understand that in the United States the young man does not generally take kindly to the idea of spending some years engaged in engineering design and can earn better promotion and money on the production floor or in the field. In England, a designer is thought to have a promising professional career ahead of him, and he can eventually become Chief Engineer of his firm, particularly if he has had previous experience in other departments before going to the design office. In any case, a young man should go through the plant (the machine shops, and the experimental and servicing departments) before entering the design office, otherwise he is likely to perpetrate "quite impossible" designs.

I would now like to say something about the suitability of British engines for production.

Recent articles in the American press have stated that we design engines that are difficult to produce in quantity. This is certainly not the case when considered in terms of production cost. All aviation engines are relatively difficult to produce, but there are none that I know of which cannot be produced in quantity by the facilities you possess, coupled with the great ability of your production specialists. Further, we built numbers of the most complex engines in the last war without unusual difficulty—and so did you, on our behalf.

When considering a licensed engine, it is important not to make any changes from the original purely to facilitate production. In fact, a licensed engine should be a "chinese copy" of the original with regard to both materials and manufacture.

An engine that has just passed the Type or Model Test is still in the early development stage and, therefore, more vulnerable to engineering and material changes. But it is quite natural to acquire the license for an engine in its early development in order to ensure the most up-to-date product when produced.

It requires great caution and restraint on the part of the licensee firm in making any engineering change, particularly for production reasons, where production may just be starting or already in full spate and if there are insufficient running hours behind the design change or modification; subsequent failure in production engines can lead to a chaotic state when dealing with the large production rates common to the United States.

Incidentally, the engine mentioned in the American Press has less critical material in its make-up than existing engines and is, therefore, all the more acceptable when considering wartime production.

British philosophy is that a completely new aviation engine must first be made to work and give its calculated performance, and there should be little or no design compromise for production's sake at the risk of

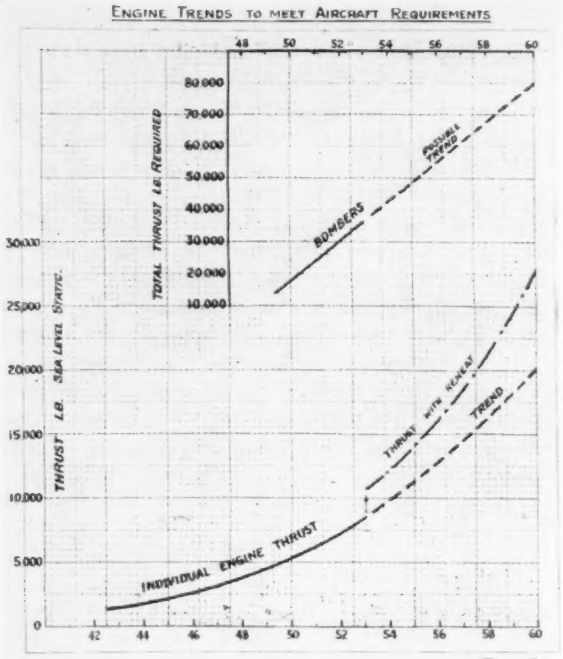

FIG. 5

failure to achieve the performance requirements. If, however, the production order is sufficiently large to warrant later a reconsideration of the design of a particular component, to help manufacture, the redesigned or "productionized" part must be subjected to considerable and intensive experimental running before it is finally approved and introduced in the engine Drawing Introduction Sheet. This is, of course, easier to accomplish with our smaller production quantities.

The various points I have attempted to make here are also intended to emphasize the importance of time and timing in this aviation business. If the timing is not right and a particular engine is produced too late and beaten at the post by a competitor (even if that engine is of somewhat inferior performance), the fact that the aircraft constructor could not depend upon getting the engine he originally wanted is sufficient to put its acceptance back some years—even for good if there is no other requirement. For this reason, and in spite of the fact that the aviation industry in all countries is nationally supported through the medium of military orders, there is considerable competition among the individual engine builders; one has only to go back through the years, to the period between the two wars, to see how the fortunes of the major firms have changed and fluctuated because of "the luck of the draw" and because a certain engine was available before others or more suited to a particular air frame.

As I have previously remarked, it is the man that matters rather than the machine. And to get experienced aviation engine designers and development engineers, it is necessary to pay them well because you are buying experience that is not in any book.

CENTRIFUGAL AND AXIAL ENGINES—THEIR RELATIVE COST

The axial-type engine is now fully accepted on its own merits of superior overall performance. This does not imply that the centrifugal has been incapable of improvement, since any engine will respond to intensive development; there are still in existence some axials that are no bettter than, or as good as, the centrifugal. But the former (axial) has practically all the advantages, although it is more costly to produce than the centrifugal engine. Our present experience, of relatively small production quantities, suggests that its relative cost would be about twice that of the centrifugal, in terms of pounds sterling per pound of engine weight.

If, however, the centrifugal were designed for the same pressure ratio as some of the present axials, then it would probably cost more than the latter—on the same costing basis.

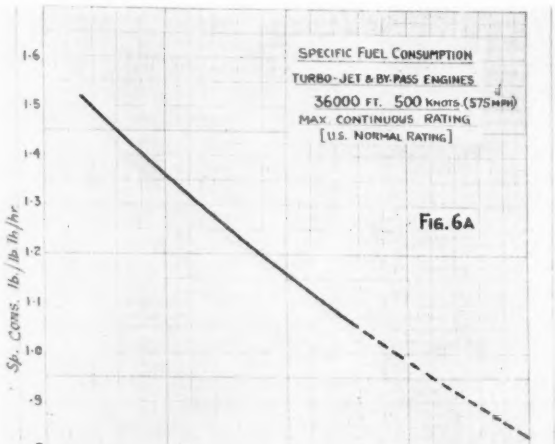

FIG. 6A

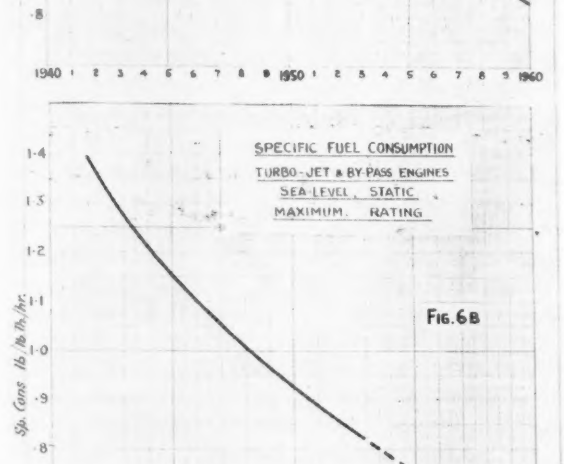

FIG. 6B

Engine Performance Testing and Calibration Facilities

Because of limited financial resources, it has not been possible for the individual firms to provide all the facilities considered necessary for the performance testing and calibration of turbojet engines, particularly at simulated altitude conditions. But we have succeeded by improvisation in obtaining surprisingly close agreement between our component tests and the performance of the full-scale engine in the air. For instance, insufficient power has been available to make compressor tests at full output and, therefore, all the compressors of our large engines have been tested and calibrated with restricted or throttled air inlets. Turbine design has been proved, and improved, by running part-scale wheels (having light-alloy blades) on cold air, and the results have read across satisfactorily to the full-scale components. Cold-air testing permits the use of light-alloy blades, which can be easily and rapidly manufactured when a new blade form is required.

The full-scale engines have then been instrumented, strain-gaged, and calibrated in fighter aircraft, and two-way radio communication between the pilot and technical personnel on the ground has been used directly to report flight readings and to permit engine conditions to be altered and controlled as necessary. In this way, the altitude characteristics of the compressor, etc., have been confirmed.

So far, we have been able to get by and have not yet felt the absolute need for an altitude test chamber for full-scale engine test. While there are already available some limited component testing facilities at the National Gas Turbine Establishment, it is realized that additional and elaborate equipment must eventually be provided to meet the engine altitude requirements for military aircraft, which are steadily increasing. Though the flying test-bed is still a necessary part of the flight development of an engine, a certain (minimum) standard of engine altitude performance will, no doubt, be demanded before the future expensive prototype aircraft takes the air. The altitude chamber will also permit the investigation of any peculiar engine behavior that may have occurred in actual flight.

There is a series of curves showing British progress in the last decade and what may be expected by 1960. The first of these (Fig. 5) shows the increase of thrust, plus reheat, expected in the future from the individual engine, and also the total thrust required for increased altitude, or load, for the subsonic bomber. Fig. 6 includes two curves giving the improvement in specific fuel consumption related to flight at the tropopause at 575 m.p.h. and, also, at static sea-level conditions In Figs. 7 and 8, the improvement in specific weight (lb. weight per lb. thrust) and the thrust per sq. ft. of frontal area, respectively, are shown, related to the same altitude-speed and to sea-level static conditions.

These curves are self-explanatory, indicating a steady improvement in engine performance during the last 10 years.

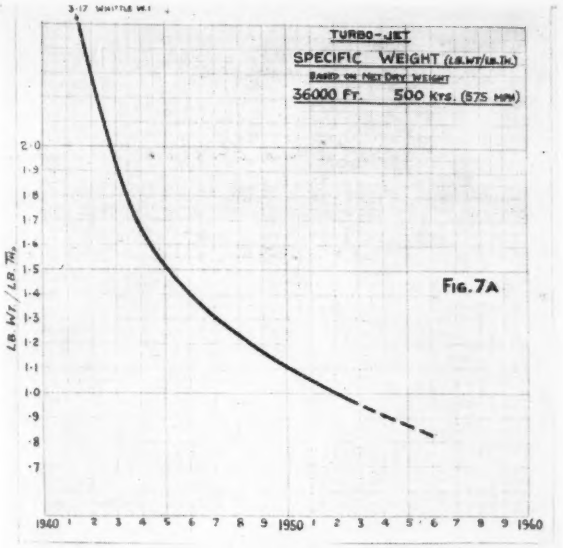

FIG. 7A

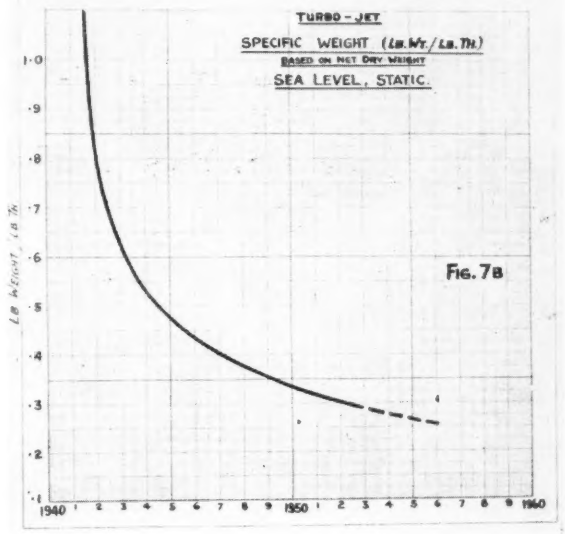

FIG. 7B

Conclusion

Success in the aviation engine industry may be summed up as the ability to profit by long experience, to make fewer mistakes than the next man and, then, to cure the unforeseen or unavoidable errors quickly.

A necessary contribution to the ultimate success of any engine is the establishment, by the engine manufacturer, of an efficient technical or field service for both the aircraft constructor and the operator (military or civil). Experienced installation and test engineers are absolutely necessary for the technical progress of the engine and its flight reliability. They also greatly assist in keeping the customer satisfied if, in addition to being capable engineers, they have the right personality to handle awkward situations. It takes some years to build up such a staff and the men must be carefully chosen and trained.

Another point is that of technical collaboration between the principal engine companies. Britain enjoys

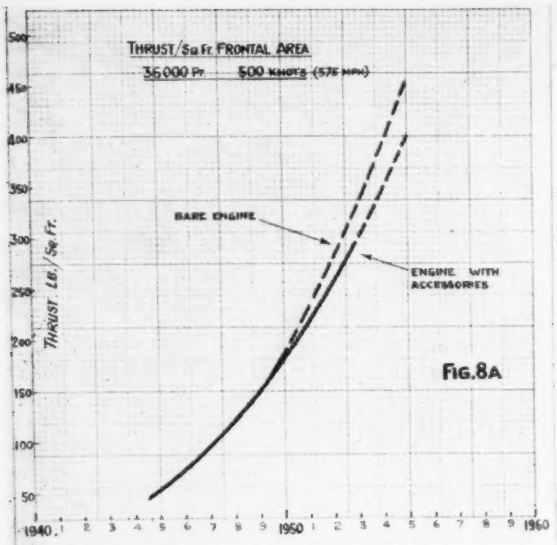

FIG. 8A

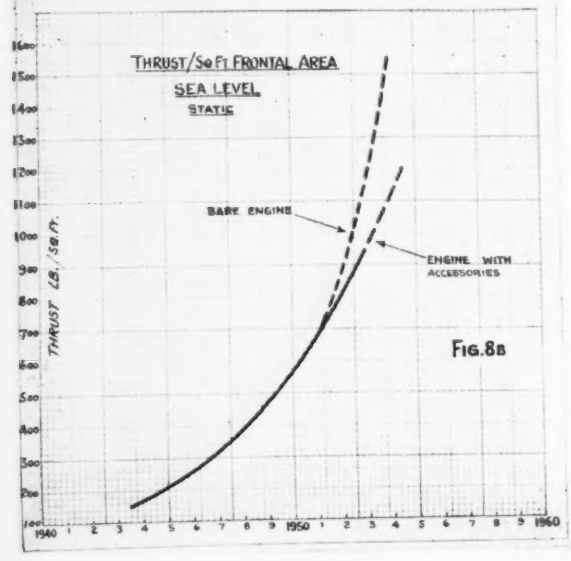

FIG. 8B

a remarkable degree of free collaboration on a firm-to-firm basis, the particular firms concerned visiting each other at regular intervals to discuss their various technical problems. In addition to which there is the Gas Turbine Collaboration Committee (formed during the War and still going strong), which meets three or four times a year to discuss the individual and collective problems and the general technical progress of the aviation gas-turbine engine. Each firm may send two representatives and, of course, the proceedings and records (minutes) are secret. The committee is under the chairmanship of the Principal Director of Engine Research and Development of the Ministry of Supply, and there are various subcommittees to progress and report on such matters as high-temperature materials, compressor design and mechanical engineering, etc.

The Gas Turbine Collaboration Committee is unique and serves as a forum to air the views and difficulties of those concerned with the development of the aviation gas turbine. It is also a "get-together" for the high-level technical personnel of the firms to "let their hair down." The main meeting usually occupies one or two days, depending upon the venue; each of the principal engine firms, including the National Gas Turbine Establishment, acts as host in turn. A tour of the host's firm is always made after the technical meeting.

None of this collaboration has affected natural rivalry and competition.

Government support, which is the mainstay of modern aviation, should be real support rather than rigid control; it should aim to be benevolent and encouraging rather than overriding and interfering. In any case, I know of no department of government capable of taking on the functions of the legitimate aviation industry to design, develop, and build aircraft and engines. The nearest approach to this was the position assumed by the Royal Aircraft Factory (now the Royal Aircraft Establishment) at Farnborough during World War I, which was responsible for the design of some interesting military aircraft and engines. But since no established industry then existed, this was a natural development. Later, as the result of the rapid growth of an aircraft industry due to the war, it was decided that the Factory should cease to do industry's rightful job and become a research and test center to aid industry in meeting the government's requirements.

Apropos of my earlier remarks regarding the rapidity with which the (new) gas turbine can be put into regular flight service, relative to the (new) piston engine, in only nine months of scheduled air-line operation the Ghost engines of the Comet show a failure rate of 0.49 per 1,000 hours' flying, which is superior to that (0.60) of two well-tried air-cooled radial piston engines. It is also of interest that John Cunningham, Chief Test Pilot of de Havilland, completed 1,000 hours of test flying in the Comet on last January 22 without any serious mishap.

I would draw to your attention an excellent publication[1] dealing with the procurement and development of the aviation engine and also to a paper[2] covering the same subject. The third paper[3] referred to deals with aircraft development and is a valuable exposition of British (Ministry of Supply) methods of aircraft, engine and equipment procurement as a whole.

Finally, always remember that the engine is the most important part of the aircraft; and its failure to perform well can, at the least, seriously jeopardize the chances of an aircraft's success, regardless of the latter's quality as a flying machine. Therefore, no effort should be spared to ensure a healthy and successful engine industry. Also remember that failure to take the next step, to order a new engine, may mean 10 years in the wilderness—i.e., a 5-year wait to see what the other fellow does, plus 5 years (at least) for the new engine.

Acknowledgment

I tender grateful thanks to my colleagues Messrs. Weir, Griffiths, Brown, Remfry, Alexander and Chap-

man, who have given me much help and advice during the preparation of this paper, and to Miss Godden for the numberless times she has retyped and assembled it.

I am indebted to the Controller of Supplies (Air), Air Marshal Sir John Boothman, and the Chief Scientist, Dr. O. H. Wansbrough-Jones, of the British Ministry of Supply, for permission to present this work.

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Propeller Reversing Problems

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Introduction

THE ADVANTAGES OF PROPELLER REVERSING are well known. First, reversing reduces stopping distances on wet or icy runways where wheel brakes are only partially effective. Second, since all approved landing distances are based on stopping with brakes alone, it provides an extra safety factor in cases of brake failure, unexpected shifts in wind direction, or landings too far down a runway.

Reversible-pitch propellers came into widespread airline use in 1947 in Douglas DC-6 airplanes. Since then, they have been used on every new transport airplane that has been built.

Accidents Prevented by Reversing

There is no way to determine exactly how many accidents have been prevented by the use of reverse thrust. Rarely does an air line or a pilot make a special point of reporting a near miss of this sort. To assess the benefits of reverse thrust we must, therefore, resort to the indirect method of studying accidents involving airplanes that do not have reversible propellers. Such a study has been made covering a period from 1947 through August, 1952. During this span there were 39 accidents that might have been prevented or, at the very least, made less severe had propeller reversing been available. These accidents resulted in 93 fatalities and 26 major injuries. Of course, the list of 39 accidents includes airplanes with conventional landing gear. On these, there may be some question as to the practicability of using reversing propellers. However, in the remaining cases, including all four fatal accidents on this list, the airplanes involved were of the tricycle-gear type. On these, reversing could undoubtedly have been used without any serious problem of handling qualities. So much for the value of reversible propellers.

Accidents Caused by Reversing

On the other side of the ledger, we are faced with the fact that these propellers have not been an unmixed blessing. There have been two fatal accidents attributed to inadvertent flight reversing. The first of these involved a twin-engined transport engaged in a training flight. The second involved a four-engined transport in scheduled passenger operation. In addition, there have been other cases of unwanted reversal which have caused or narrowly missed being serious incidents.

Causes of Unwanted Reversal

These cases have led to a searching analysis of the possible ways in which unwanted reversal has occurred or can occur. The two most important categories of faults which can cause such troubles are: (1) electrical faults in the propeller control system and (2) inadvertent movement of the throttle into reverse in flight.

In all reversing systems, the control of reverse pitch is achieved by throttle motion. When the throttle is moved aft beyond the normal idle position, it actuates electrical switches that send a reversing signal to the propeller, thus causing the blades to move to negative pitch. Further rearward movement of the throttles *increases* engine throttle opening, applying more power to the reversed blades and increasing reverse thrust. When the throttles are again moved forward, power is first reduced, although the propeller remains in reverse. When the throttle returns to the forward idle position, the reversing signal is terminated and the blades return to normal pitch.

Electrical Faults

Application of electrical energy to any part of the reversing circuit between the throttle switch and the propeller would have the same result as deliberate movement of the throttle into reverse. In other words, if the reversing device receives an electrical signal, it is unable to discriminate as to the source of the signal. Therefore it proceeds dutifully to do its job of reversing the propeller whether the signal is a true reversing signal initiated by the pilot or whether it is a stray signal resulting from some electrical fault in the airplane.

Electrical Terminals

Stray signals of this sort are by no means common—not nearly so frequent, for example, as grounds or open circuits. Nevertheless, there is an ever present possibility of inadvertent electric power application. The most vulnerable parts of the system are terminal points and connectors. At terminal strips or relays there may be many wiring connections in close proximity to each other. A terminal carrying a reversing wire may be adjacent to terminals that carry current to serve

Presented at the Air Transport—Safety Session, Twenty-First Annual Meeting, IAS, New York, January 26–29, 1953.

various other electrical devices. At many such terminal points, bare metal parts of the reversing circuit are exposed to possible contact in case of loose connections. The most obvious remedy is the elimination of as many such terminals as possible. Where terminals must be used, the provision of entirely separate terminal points for the reversing circuit is desirable. Another, although less desirable, alternative is covering the reversing circuit terminals with some suitable insulation and securing all wires to prevent movement in case of breakage or loosening.

Electrical Connectors

Another point of electrical vulnerability is the commonly used multiple connector plug. Here, particularly where the wires are soldered to the connector pins at the back of the plug, there is a possibility that a faulty connection might result in undesired reversing signals. Elimination of connectors or the use of separate connectors is the most desirable practice. Again, a less attractive alternative is to surround the critical pin in the connector with pins that are either inactive or connected to ground.

Wiring Isolation

Wiring runs themselves are subject to occasional faults, although the likelihood is not so great as at connections. Nevertheless, deterioration of insulation can occur due to heat, improper handling, or exposure to the elements. Chafing of insulation at supports or against structure is also a possibility. Good design practice to prevent such faults calls for routing the vulnerable wires away from all other energized circuits or running them through completely separate conduit. Instead of conduit it has been found more convenient in many cases to use wire with an external shielding which can be grounded to the structure of the airplane.

Throttle Arrangement

So much for electrical faults and precautions against them. Let us now consider the second type of problem encountered in service with reversing propellers—accidental movement of the throttle levers back into the reverse position. As previously explained, movement of the throttle into reverse initiates a sequence of events which sends the propeller blades to negative pitch and applies power to the engine. Whether the throttle is moved to reverse deliberately or accidentally is, again, unknown to the propeller and its electrical circuit. Intentional or not, the result is reversing.

Throttle Lock Actuated by Landing-Gear Switch

To prevent movement of the throttles into reverse, the pilot must be provided with some type of throttle stop or lock which limits throttle movement in flight to the positive sector of the quadrant. Every airplane equipped with reversible propellers has a lock of this type. This lock is closed during flight and retracts when drawn to the open position as a result of closure of a switch on the landing gear. This switch is so arranged that it opens the lock when the airplane is on the ground and the landing gear has been deflected by the weight of the aircraft compressing the oleo strut. With the lock in place and properly adjusted, the pilot cannot pull the throttles into reverse.

Throttle Lock Override and Warning

In case of failure of the lock to open as intended on the ground, it would be impossible to use reversing even in an emergency unless some provision were made to permit the crew to open the lock. This has been done in most cases by providing a linkage that will permit manual operation in an emergency. The manual override serves another vital purpose in all cases. It is mechanically linked to the lock. If the lock is open the override lever moves to the "lock-open" position. thereby alerting the crew and cautioning the pilot that he must be particularly careful when the throttles are retarded to avoid moving them too far and inadvertently getting into reverse.

Distinctive Throttle Motion

Examining a system such as the one described, you can see that the provision of a lock and warning device still leaves something to be desired. As an obvious minimum, if the lock should for any reason open in flight, it is still vital to have some positioning device so that the pilot will know the safe limit of rearward throttle movement. Furthermore, if the warning device should go unnoticed, as can well be the case at night during landing under adverse traffic and weather conditions, the pilot may move the throttle back past the idle position unless the positioning device limits his natural movement. Three devices have been used in various transports to accomplish this.

Detent-Type Throttle

The first of these devices has a spring-loaded detent to provide an indication of the location of the forward idle position. The spring-loaded ball requires a greater force to be exerted to move past this point. However, there is no change in the direction of throttle movement. The chief advantage of this design is the ease with which reversing can be achieved or stopped as required in any type of emergency. The disadvantage is the fact that the detent is ineffective if the throttle is moved rapidly. As an example of the type of incident that can occur, one airplane with this type of throttle was involved in a reversal in the air following a bounce on landing. Because of a combination of circumstances the airplane approached the ground at a rather high rate of descent and with power partially on. Because of the rapid descent, it bounced back into the air after ground contact. Attempting to get it back on the ground, one of the pilots closed the throttles just as the reverse lock opened due to the momentary ground im-

pact that actuated the landing-gear switch. Reversal occurred while the airplane was air borne after the bounce.

Lift to Reverse Throttle

There is another throttle design that is less vulnerable to the faults of the detent. In this arrangement the throttles are made in two sections—one sliding along the axis of the other. The movable section is held down by spring pressure unless a lifting force is applied. This movable part carries a pin or lug that, in the forward idle position, bumps against a positive stop. To move the throttle further aft, it must be lifted to pass over the stop. A desirable feature of such a design is a track or cam that prevents lifting the throttle at any point ahead of the forward idle position.

Auxiliary Reversing Levers

There is still another throttle arrangement used to actuate reversing systems. In this design the primary throttle levers do not actuate reversing. They can move only as far as the positive idle position and cannot go any further. To reverse the propellers, the pilot must grasp a set of auxiliary levers that pivot about a point on the primary levers and which protrude forward. The upward and rearward movement of these levers actuates a linkage that operates the reversing switches. The system is so arranged that the auxiliary levers can only be raised when the throttles are in the idle position. Similarly, the main throttles can be advanced only after the reversing levers have been returned to the normal or forward-pitch position.

With this arrangement there is no way that the primary throttles can be mismanaged and thus result in reversing. Furthermore, the movement required to shift the grip to the reversing levers is so distinctive that no pilot is likely to do so without full realization of what he is doing.

Additional Reversing Safety Device

I have explained up to this point the types of problems that have been experienced with reversing electrical systems and throttle arrangements and what measures can and are being taken to guard against them.

Another measure that has received considerable attention is the addition of what might be called a duplicate reversing control that would be in series with the present control. Such a control would require a separate means of actuation from the cockpit. It would prevent reversing in case of accidental actuation of the normal reversing control, since its series arrangement with the present system would interrupt the reversing signal from the present reversing device before it could reach the propeller.

The addition of such a control, of course, provides added security against inadvertent reversing. However, it has the disadvantage of additional complication of the system. It adds to the possibility of failure to reverse, since it doubles the number of control components which can fail. Nevertheless, unwanted reversing in flight can be so serious a matter that the need for security against its happening warrants serious consideration of such a device.

Reverse-Pitch Indication

Another safety device associated with reversing propellers is the reverse-pitch indicator. Indicators can be used with modern propeller designs to provide the crew with a signal when reversing occurs. The chief value of such an indicator lies in day-to-day use during normal applications of reverse thrust on the ground. In case a propeller fails to reverse or is slow in reversing when the throttles are moved rearward, the airplane is subjected to asymmetrical thrust. On slippery or wet runways this can result in loss of directional control. With reverse-pitch indication available, the pilot will have warning in case this occurs and can at least minimize the control problem by avoiding the use of power or delaying power application. As an added attraction, reverse-pitch indicators would also provide warning in case of reversal in flight and would help the crew to make a rapid and accurate analysis of the difficulty and of the remedial action they should take.

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A Simple Thrust Indicator for Propeller-Driven Airplanes

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ABSTRACT

When a propeller reverses inadvertently, the indications available to the pilot are in many instances insufficient to permit a rapid and correct diagnosis of the difficulty. The large and asymmetrical loss in thrust may lead to loss of control unless prompt and correct action is taken.

A simple thrust indicator, based on a measurement of the rise in total pressure through the propeller disc, is proposed. Since this instrument senses directly the all-important quantity of thrust, it provides a positive indication of propeller reversal. The sensitivity of the indicator in all flight régimes suggests its use in other applications such as a monitor of engine operation.

The principle of operation, operating characteristics, and installation considerations are discussed.

INTRODUCTION

THE INADVERTENT REVERSAL of a propeller on a multiengined airplane during a critical flight condition such as take-off or landing presents a serious flight situation. The danger lies in the large and asymmetrical change in thrust, resulting in possible loss of control.

Under the proper conditions a propeller is capable of producing more negative thrust than it is normally able to produce in the positive direction. When one propeller on a four-engined airplane reverses, for example, the available thrust may be reduced by more than 50 per cent, as illustrated in Fig. 1. This enormous loss in thrust and the large change in trim are the basic causes of trouble. In a twin-engined airplane the situation is obviously much worse.

Propeller reversal is such a serious type of failure that efforts now under way to make safeguards against inadvertent reversal more foolproof should not be relaxed. Of course, loss of thrust may also be caused by other failures, such as of the engine itself or the propeller governor.

Whenever a serious loss in thrust does occur, prompt action by the pilot to counteract the malfunctioning is necessary. It is not always possible to diagnose the trouble quickly with present instrumentation—at least in sufficient time to recover safely. It seems also possible, as a study of a recent serious accident suggests, to misinterpret the danger signals now available and to compound the difficulties by taking incorrect action. An instrument capable of detecting any loss in thrust, whatever the cause, seems desirable.

A thrust indicator is proposed which, from preliminary trials, appears to be simple, sensitive, direct, and reliable. This instrument is a simplification of a method of thrust measurement which has been used successfully by the National Advisory Committee for Aeronautics during more than 10 years of propeller flight research.

DESCRIPTION OF THRUST INDICATOR

General Arrangements.—Two total pressure heads are mounted in the propeller slipstream. They are located behind the 0.7 radial station and are diametrically opposed above and below the propeller axis. The pressure lines from these two heads are tied together to obtain an average pressure, which is then applied to the total, or pitot, side of an air-speed indicator. The static side of the air-speed indicator is connected into the pitot pressure line from the airplane air-speed head. The indicator dial is recalibrated to indicate suitable units of pressure, both positive and negative. This comprises the entire thrust-indicating system. A schematic layout of the system as installed in a C-45 airplane is shown in Fig. 2.

Principle of Operation.—Reduced to its simplest form, a propeller becomes an actuator disc operating in an incompressible fluid. According to this concept, originally developed by Rankine and Froude and thoroughly described in reference 1, the propeller becomes a mechanism capable of maintaining a uniform pressure difference between front and back of the plane of rotation.

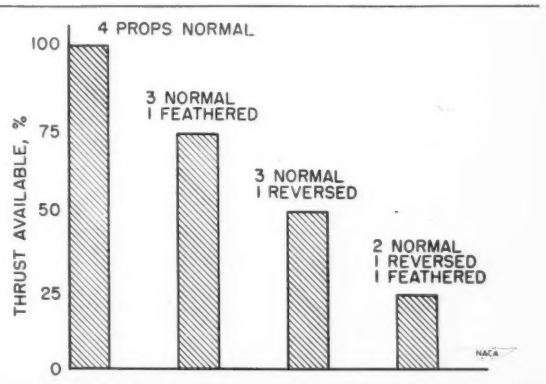

FIG. 1. Approximate variation of available thrust with régime of propeller operation—four-engined airplane.

Presented at the Air Transport—Safety Session, Twenty-First Annual Meeting, IAS, New York, January 26–29, 1953.

* Aeronautical Research Scientist.

† Chief, Flight Research Division.

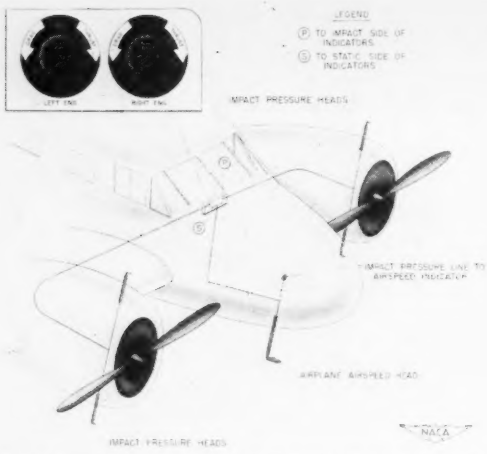

FIG. 2. Schematic arrangement of thrust indicators as installed in C-45 airplane.

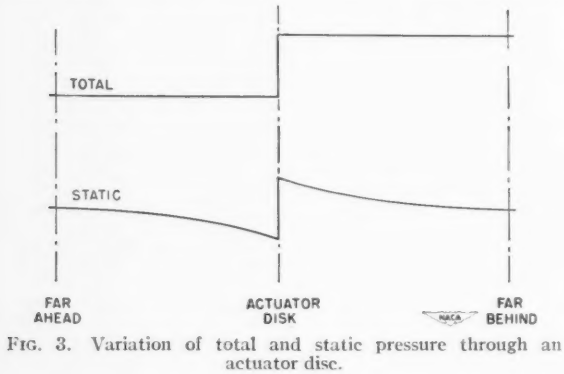

FIG. 3. Variation of total and static pressure through an actuator disc.

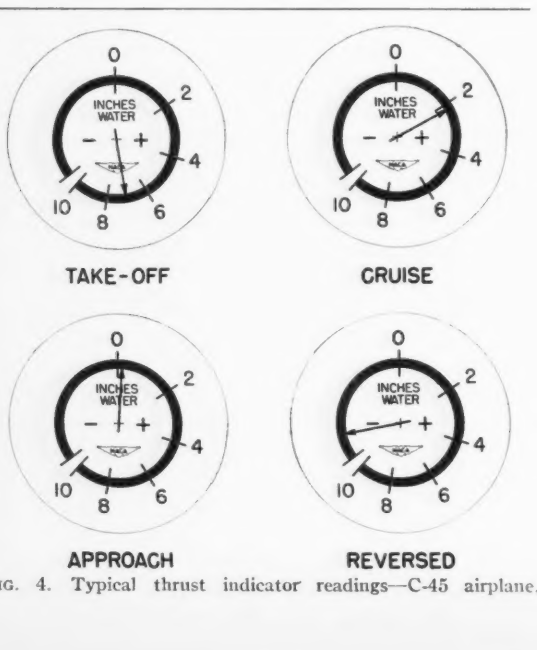

FIG. 4. Typical thrust indicator readings—C-45 airplane.

The variations in pressure through the disc are as shown in Fig. 3. Total pressure ahead of the disc is constant at the free-stream value, jumps to a higher value (for positive thrust) across the disc, and remains constant again downstream. Static pressure decreases from the free-stream value as the disc is approached, also changes across the disc to a value higher than free stream, and then decreases gradually to the free-stream value far downstream. The jump in static pressure is equal to the jump in total pressure. The pressure difference across the disc, acting over the disc area, produces the thrust force.

It is immaterial whether thrust is sensed by the change in static pressure or by the change in total pressure. Total pressure is selected, however, because it is much easier to measure than static pressure and because the fore-and-aft location of the measuring point (as shown in Fig. 3) is relatively unimportant.

Typical indicator readings for several flight conditions are shown in Fig. 4.

Except for the propeller-reversed condition, these readings were obtained during exploratory tests of an installation on a C-45 airplane. The propeller-reversed reading is an estimate of what might occur during take-off.

Possible Applications.—For most uses, only a qualitative measure of thrust is required, and this is provided by the proposed indicator without elaborate calibration. It is only necessary to establish normal readings under normal operating conditions. In multi-engined airplanes, if all engines are equipped with identical installations, normal operation (of each engine) would be continuously indicated by similar dial readings.

Because of the limitations inherent in a single- or two-point survey system, elaborate calibrations would be necessary only if use of the indicator for quantitative measurements of thrust is required. Many factors such as design details of propeller, propeller-engine-air-frame interference, and operating parameters affect the calibration. Usefulness of the device as a trouble indicator, however, is not impaired.

The instrument will indicate with certainty whenever thrust is varied due to propeller reversal, governor, or engine failure. During ground maneuvering, the indicator may be used to determine whether a propeller is in positive or negative pitch before airplane movement occurs.

The sensitivity of the instrument suggests its usefulness as a detector of even minor engine malfunctioning. In the C-45 installation, for example, an air-speed indicator with a range of 140 m.p.h., or 10 in. of water, was required to register full static thrust. In the cruise condition the meter reads about 2 in. of water. Since the meter is accurate to about $\frac{1}{2}$ per cent of full-scale pressure, any change in thrust during cruise operation greater than about 2 per cent could be noted.

Consideration Affecting Satisfactory Installation

While the proposed thrust indicator is extremely simple, being nothing more elaborate than an ordinary air-speed system, a satisfactory installation requires that consideration be given to several factors that arise as a result of the differences between the idealized conditions of an actuator disc and an actual configuration.

Nonuniform Radial Distribution of Thrust.—Unlike the actuator disc, the total pressure difference across the propeller disc varies with radius roughly as shown in Fig. 5. The shape of this pressure distribution curve is basically the same for all conventional propellers. Neglecting, for the moment, the effects of pitch and yaw, variations from this basic shape are caused by factors such as hub and spinner design, flight speed, and Mach Number. It is these factors that require the use of multiple-point surveys and extensive flight tests if accurate quantitative measurements are desired. For the intended use of the proposed indicator, however, it is only necessary to find a radial station at which the variation of total pressure with thrust is nearly linear. An analysis of a large number of complete survey measurements indicates that the 0.7 radius station is most suitable. In addition to varying nearly linearly with thrust, the pressure behind this station is also generally greater than elsewhere, thus providing highest sensitivity. Other stations (from about 0.4 to 0.9 radius) could, however, be used almost as effectively.

Flow Periodicity.—Behind conventional propellers, with relatively few blades, a periodic oscillation in both pressure and flow direction exists, with a frequency equal to the frequency of blade passage. These oscillations are greatest close behind the disc and decrease in amplitude with distance downstream. Because of these fluctuations, it has been found desirable to place the survey heads at least one-quarter propeller diameter behind the disc. The oscillations remaining may then be easily damped with small-bore tubing so that steady readings are obtained at the indicator.

Effect of Pitch and Yaw.—As long as the propeller axis is aligned exactly with the air stream, the average pressure behind any radial station remains constant regardless of circumferential location. Whenever the axis is inclined to the air stream, each blade section experiences an effective increase in angle of attack through half of one revolution and a decrease through the other half. As a result, a variation in thrust with circumferential position is produced which oscillates nearly sinusoidally about an average value. A detailed discussion of this phenomenon is given in reference 2.

Survey tubes mounted along a horizontal axis are most seriously affected by pitch and little affected by yaw. Conversely, tubes mounted on a vertical axis are most affected by yaw. Because of these effects, a single-tube survey is not satisfactory for a thrust indicator. The undesirable effects of pitch and yaw are satisfactorily overcome by using two interconnected, diametrically opposed heads to provide a very nearly correct average pressure for the indicator. Since large angles of yaw are rarely encountered in normal operations, the effects of inclination are further reduced by mounting the two heads on a vertical axis.

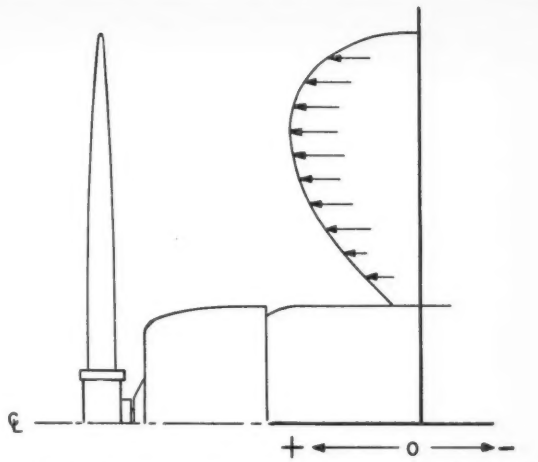

Fig. 5. Variation with radius of total pressure rise behind propeller disc.

Finally, a word of caution concerning the airplane air-speed head, which is used to provide the free-stream total pressure reference. In many installations the air-speed total pressure head is subject to significant errors due to either yaw or pitch. If this is the case, the thrust indicators may give erroneous readings when large angles of yaw are encountered. Relocation of the air-speed head or use of a separate shielded total pressure tube for the thrust indicators might be desirable.

Indicator Range.—Standard air-speed indicators may be used as thrust indicators by virtue of the fact that operation in the negative direction, although usually restricted, is possible. Since a full negative thrust range is normally not required, this restriction is not serious.

Maximum positive thrust occurs under static conditions. To sense this thrust requires a positive pressure range from about 8 to 13 in. of water (or from about 140 to 160 m.p.h. indicated air speed), depending upon the power-disc loading of the engine-propeller combination.

At constant power, propeller thrust varies inversely with speed. Indicator readings on airplanes cruising at high speed under reduced power may therefore be low with respect to the full-power static thrust reading. Accuracy of the indicator as a monitor of engine operation may thereby be decreased. To some extent the high Mach Number associated with high cruising speed is helpful, since it, in effect, tends to increase instrument sensitivity (25 per cent at a Mach Number of 0.7, as determined from reference 3). However, for such applications, it may be desirable to transfer to lower range indicators for cruising.

Type of Head.—Any standard type of total or pitot head which is properly drained and deiced should be satisfactory.

Concluding Remarks

Because of the apparent simplicity and reliability of the proposed thrust indicator, it should find application wherever a sensitive measure of thrust or thrust change is required. Since it senses the all-important quantity of thrust directly, it might also be arranged to initiate propeller feathering and engine shutdown whenever thrust changes from positive to negative. The interpretation and reaction times thus eliminated could, under critical conditions, easily be the difference between safe recovery and disaster.

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On Programs for

Tests Involving Several Variables*

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Shell Development Company and Shell Oil Company, Respectively

(1) Introduction

Since technological progress depends at an increasing rate on more and better experimental data, greater effort is spent on measurements and on the development of more elaborate (and more expensive) instruments and methods. Frequently the observed quantity depends on several factors or independent variables. With the increasing number of such factors, the amount of work required for an investigation of their combined influence increases rapidly. Under such conditions careful programing of the required tests is worth while, especially if the tests are time consuming or expensive.

The question of programing is best discussed in an example. If the influence of two additives, say nickel and chromium, on the fatigue life of a steel under practical conditions is to be investigated, several factors must be considered. Most important are, of course, the amounts of the two additives present in the steel. The load conditions—namely, the average load and the difference between the maximum and minimum load, should be varied within the practically important range. Other factors may be of interest—e.g., the temperature.

According to the traditional method, the influence of these five variables on the fatigue life is examined according to the following scheme. A standard level is established for each of the five variables. In a first set of tests, only the amount of the first additive is varied, while all other variables are kept on the standard level. In a second set, only the second variable changes, etc. In general, we need other sets of tests to obtain information as to whether the influences of two variables are simply superimposed on each other.

In the present example, for instance, the increase of fatigue life due to *two* additives may be quite different from the sum of the increases produced singly by each of them. Such a deviation from simple superposition of influences is frequently called "interaction" of variables. In general, the existence and magnitude of interactions is to be examined. Even the study of higher interactions, the combined effect of three or more variables, may sometimes be desirable, but any such programing obviously reaches a practical limit quickly.

Flexibility is the advantage of the traditional method of programing. More tests can be made on the study of the more important factors, and the program can be modified in this manner any time during the test series in accord with the results already obtained. For instance, if the interesting temperature range is small, say from 32–120°F., the influence of temperature may turn out to be of minor importance. Consequently, few tests will be scheduled for determining the influence of temperature.

Such programing, however, leads to a certain bias. In our example, most of the tests will be carried out at the chosen standard temperature, say 70°F. The total result of the series, therefore, will not be perfectly representative of the whole temperature range from 32–120°F. By treating temperature as a minor variable, uniformity in covering the whole field has been lost.

The loss is particularly serious if a variable cannot be fully controlled. In the present example, suppose that samples have been obtained from three different sources. We are not particularly interested in the presumably small differences that may exist between the samples from various sources, but we have to make sure that such differences do not falsify the results obtained for the influence of the five variables. In the traditional method, there is no other way but to treat the source as a sixth variable and to schedule a series of tests for comparison of the sources. These tests are lost for the principal object regardless of whether any such differences exist.

Agricultural research is practically always confronted with variables that cannot be controlled—e.g., with the variable soil conditions in a set of test plots.

A different programing method,** therefore, the so-called "statistical" method of orthogonal squares, has been long in use for agricultural tests. Its application to the previous problem is illustrated in Table 1. Let us denote by A, B, and C three different contents of nickel in the steel, three contents of chromium, and three temperatures within the desired range. The three sources, too, are denoted by A, B, and C. Each variable has a definite place, indicated by the code, in each small square. The schedule of Table 1 means that the fatigue life is to be determined for nine samples at the conditions specified by the small squares.

Received January 2, 1953.

* The present investigation of test-planning methods started from a flight research project carried out under contract with the United States Air Force (Contract No. AF 33(038)-3093; Project No. MX-587, MX-789). The authors appreciate the interest shown by Dr. A. G. Cattaneo and D. N. Harris.

† Supervisor, Development.

‡ Senior Engineer, Product Application Department.

** Fisher, R. A., *The Design of Experiments;* Oliver and Boyd, London, 1949.

Table 1. Orthogonal Square

Code:	Ni	Cr
	Temp.	Source

A	A	B	A	C	A
A	A	B	B	C	C
A	B	B	B	C	B
B	C	C	A	A	B
A	C	B	C	C	C
C	B	A	C	B	A

The schedule follows a principle directly opposite to that of the traditional method. If we compare *any two* of the tests, we find that only one of the variables has the same value in both, all others are changed. In the traditional method, tests are scheduled as far as possible so that only one variable is changed, all others remaining fixed.

The advantage of the statistical method is the uniform covering of the whole range. In the three tests of the first column, the nickel content is A. At the same time, each of the other variables assumes all three values A, B, and C. The same holds for the second column where the nickel content is B and for the third with the nickel content C. The influence of the nickel content is, therefore, fairly well represented by the average results of the first, second, and third column, not for fixed standard levels of the other variables but for an average of conditions throughout the whole range.

In particular, if there are differences between the sources of the samples, they average out because all three sources are used for the tests with nickel content A, etc. The influence of the source can also be found—namely, by averaging tests 1, 5, and 9 for source A; 2, 6, and 7 for B; and 3, 4, and 8 for C. If there is no noticeable difference between the sources, the tests give better information regarding the influence of the other variables. No test is lost for the final result.

The principal property of an orthogonal square can be described as follows: While any variable is kept at a fixed level, any other variable assumes once each of the g levels assigned to it. The size of the square is g, the number of tests g^2($g = 3$ in Table 1).

The number of independent variables which can be arranged in an orthogonal square depends on its size g. If g is a prime number, $g + 1$ independent variables can be used. No simple rule exists for values of g which are not prime numbers. In the present example, a 5 by 5 square can be used if, together with the four variables of Table 1, the influence of the load conditions is also to be studied.

The statistical method prescribes a rigid test program. This is a disadvantage in exploratory work but not in routine measurements, especially if the tests are carried out by a semiskilled observer.

Although the statistical method appears to present considerable advantages for a variety of technical problems, it has been rarely used outside the field of agricultural and biological research. The reasons for this limitation will be discussed in the following section.

(2) Interaction

A set of measurements of a quantity y, determined at various levels of the independent variables z_1, z_2 . . ., can be represented for subsequent applications in various ways. If we have no advance information, we shall, in general, approximate the results by means of a power series

$$\begin{aligned} Y = f &+ f_1 z_1 + f_2 z_2 + f_3 z_3 + \cdots\cdots \\ &+ f_{11} z_1^2 + f_{22} z_2^2 + f_{33} z_3^2 + \cdots\cdots \\ &+ f_{12} z_1 z_2 + f_{13} z_1 z_3 + \cdots\cdots \\ &+ f_{23} z_2 z_3 + \cdots\cdots \end{aligned} \tag{2.1}$$

Using the symbols S_i, S_{ij} . . . for summation over the subscripts, we can write more shortly

$$Y = f + S_i(f_i z_i) + S_i(f_{ii} z_i^2) + S_{ij}(f_{ij} z_i z_j) + \cdots \quad (i \neq j) \tag{2.2}$$

The experimental data are represented for practical use as soon as the coefficients f, f_i, f_{ii}, f_{ij} . . . are calculated.

The coefficients f_{ij} (and coefficients of higher order such as f_{iij} and f_{ijk}) with unequal subscripts are the interaction coefficients. If all of them are negligible, the function y is the sum of a constant f, a function

$$f_1 z_1 + f_{11} z_1^2 + \cdots \tag{2.3}$$

of z_1 and of similar functions of z_2 alone, z_3 alone, and so on. In this case the influences of the various factors z_1, z_2 . . . are simply superimposed on each other. Practically, this special case is important because a linear function usually presents a first approximation, and a linear function, of course, contains no interaction terms. As soon as a better approximation is desired, however, interaction terms may appear. This occurs frequently in technical problems.

If all interaction coefficients are negligible, the statistical method leads to the partial functions of the type in Eq. (2.3) by an averaging procedure briefly mentioned in the preceding section. Then the calculation of the coefficients is easy. No practical procedure is known if interaction terms are present.

The method, therefore, is always good for a linear approximation. But if linear dependence may be presupposed, the number of tests prescribed by an orthogonal square is appreciably greater than the number of coefficients to be determined. This is desirable if the average error of a single measurement is so high that one

needs repeated tests in order to obtain a satisfactory accuracy of the final result. As a rule, this situation prevails in agricultural and biological research. Sometimes it occurs in technical problems, for instance, in the determination of failure properties such as tensile strength. But in many technical problems the margin between the number of tests and the number of coefficients to be determined need not be large.

On the other hand, a better than linear approximation is frequently desirable in technical research. Already for a quadratic approximation the margin between tests and coefficients reaches, in general, the desirable minimum. Higher than linear approximations are therefore a proper field of technical applications of the statistical method. But here the use has been restricted by the necessary presupposition that interaction terms are negligible. Actually, this assumption can seldom be justified in advance.

The extensive use of the statistical method in technical research depends, therefore, on a convenient procedure for calculating the coefficients of the power series in Eq. (2.2) from experimental data if the interaction coefficients are not negligible.

(3) Symmetric Squares

Orthogonal squares can be designed in numerous different arrangements. In order to find a practical calculation procedure for the case of interacting variables, one may ask: Is there a particular type of orthogonal squares for which the calculation of the coefficients in Eq. (2.2) is especially simple? Such a particular type exists. Arrangements of this type will be briefly called "symmetric squares."

Any orthogonal square of size g schedules tests involving g selected levels of any independent variable (cf. Table 1). It is always very convenient to choose *equidistant* levels so that the difference between two adjacent levels of a variable i has the fixed value d_i. For the present method, the selection of equidistant levels is indispensable.

Only squares of odd size will be discussed. Even squares are less important practically. If necessary, the corresponding relations for even squares can be derived without difficulty.

The size g of an odd square can be expressed by

$$g = 2h + 1 \tag{3.1}$$

where h is a positive integer. The g selected values of a variable z_i can then be numbered by means of the integers p from $-h$ to h. In the example shown in Table 2, a quantity should be measured at temperatures between $-5°$ and $55°$ C. It is decided to carry out the measurements at five temperatures so that $g = 5$ and $h = 2$. The distance between two adjacent selected values is

$$d_i = [55 - (-5)]/4 = 15° \tag{3.2}$$

The average temperature is

$$w_i = [55 + (-5)]/2 = 25° \tag{3.3}$$

Table 2. Example of Reducing a Variable

Five values between -5 and 55°C

$w_i = 25°$; $d_i = 15°$

z_i	-5	10	25	40	55
$p = x_i$	-2	-1	0	1	2

Table 3. 5 x 5 SYMMETRIC SQUARE

Code:

x_0	x_r
x_1	x_4
x_2	x_3

$x_r = a$

$x_0 = b$

b ⟶

a ↓									
-2	-2	-1	-2	0	-2	1	-2	2	-2
1	0	2	1	-2	2	-1	-2	0	-1
-1	2	0	-2	1	-1	2	0	-2	1
-2	-1	-1	-1	0	-1	1	-1	2	-1
2	-1	-2	0	-1	1	0	2	1	-2
1	0	2	1	-2	2	-1	-2	0	-1
-2	0	-1	0	0	0	1	0	2	0
-2	-2	-1	-1	0	0	1	1	2	2
-2	-2	-1	-1	0	0	1	1	2	2
-2	1	-1	1	0	1	1	1	2	2
-1	2	0	-2	1	-1	2	0	-2	1
0	1	1	2	2	-2	-2	-1	-1	0
-2	2	-1	2	0	2	1	2	2	2
0	1	1	2	2	-2	-2	-1	-1	0
2	-1	-2	0	-1	1	0	2	1	-2

The selected values of z_i and the corresponding values of p are given in Table 2.

The permitted integers p, together with the fixed distance d_i and the average value w_i, are sufficient to characterize the levels of z_i. The values of p can, therefore, be used as a variable x_i replacing z_i. The transformation is given by

$$z_i = w_i + d_i x_i; \qquad x_i = (z_i - w_i)/d_i \tag{3.4}$$

where x_i assumes only the values p—namely,

$$x_i = -h, -h + 1, \ldots -1, 0, 1 \ldots h - 1, h$$

The variables x_i will be called *reduced*.

"Symmetric" squares are designed by means of these reduced variables. The symmetric square for $g = 5$ is shown in Table 3. As indicated there, one coordinate, $x_r = a$, is the number of the row; another one, $x_0 = b$, is the number of the column.

Inspection of Table 3 shows that any variable assumes once each of the five prescribed values while any other variable is kept constant. The square is therefore orthogonal. In addition, it has the following particular property: In the central field all variables are zero. Any other field can be matched with a field in

Table 4. COORDINATES IN A 5 x 5 SQUARE

No.	x_r	x_0	x_1	x_2	x_3	x_4	x_1^2-2	x_2^2-2	x_3^2-2	x_4^2-2	x_1x_2	x_1x_3	x_1x_4	x_2x_3	x_2x_4	x_3x_4
1	-2	-2	1	-1	2	0	-1	-1	2	-2	-1	2	0	-2	0	0
2	-2	-1	2	0	-2	1	2	-2	2	-1	0	-4	2	0	0	-2
3	-2	0	-2	1	-1	2	2	-1	-1	2	-2	2	-4	-1	2	-2
4	-2	1	-1	2	0	-2	-1	2	-2	2	-2	0	2	0	-4	0
5	-2	2	0	-2	1	-1	-2	2	-1	-1	0	0	0	-2	2	-1
6	-1	-2	2	1	0	-1	2	-1	-2	-1	2	0	-2	0	-1	0
7	-1	-1	-2	2	1	0	2	2	-1	-2	-4	-2	0	2	0	0
8	-1	0	-1	-2	2	1	-1	2	2	-1	2	-2	-1	-4	-2	2
9	-1	1	0	-1	-2	2	-2	-1	2	2	0	0	0	2	-2	-4
10	-1	2	1	0	-1	-2	-1	-2	-1	2	0	-1	-2	0	0	2
11	0	-2	-2	-2	-2	-2	2	2	2	2	4	4	4	4	4	4
12	0	-1	-1	-1	-1	-1	-1	-1	-1	-1	1	1	1	1	1	1
13	0	0	0	0	0	0	-2	-2	-2	-2	0	0	0	0	0	0
14	0	1	1	1	1	1	-1	-1	-1	-1	1	1	1	1	1	1
15	0	2	2	2	2	2	2	2	2	2	4	4	4	4	4	4
16	1	-2	-1	0	1	2	-1	-2	-1	2	0	-1	-2	0	0	2
17	1	-1	0	1	2	-2	-2	-1	2	2	0	0	0	2	-2	-4
18	1	0	1	2	-2	-1	-1	2	2	-1	2	-2	-1	-4	-2	2
19	1	1	2	-2	-1	0	2	2	-1	-2	-4	-2	0	2	0	0
20	1	2	-2	-1	0	1	2	-1	-2	-1	2	0	-2	0	-1	0
21	2	-2	0	2	-1	1	-2	2	-1	-1	0	0	0	-2	2	-1
22	2	-1	1	-2	0	2	-1	2	-2	2	-2	0	2	0	-4	0
23	2	0	2	-1	1	-2	2	-1	-1	2	-2	2	-4	-1	2	-2
24	2	1	-2	0	2	-1	2	-2	2	-1	0	-4	2	0	0	-2
25	2	2	-1	1	-2	0	-1	-1	2	-2	-1	2	0	-2	0	0

which the variables have the same values but with opposite sign. In Table 3, these pairs are arranged symmetrically with respect to the center.

The practical value of these symmetric squares rests on the following conclusion. If we select an odd number of variables, say x_1, x_2, and x_3, multiply them, and add the 25 products for the whole square, the result is zero, or

$$S(x_1x_2x_3) = 0 \qquad (3.5)$$

where S prescribes summation over the whole square. The reason is obvious. Any of the pairs mentioned before contributes zero to the sum in Eq. (3.5) because the two products are equal but have opposite sign. Also the contribution of the central square is zero.

Relations such as the one shown in Eq. (3.5) hold for any product of variables of odd order. Since the calculation of the coefficients by the method of least squares is based on similar sums of products, dropping out the terms of odd order greatly simplifies the problem. Some other symmetry properties of these squares are also helpful.

It can be demonstrated that $g + 1$ variables can be arranged in a symmetric square if g is a prime number. This is the maximum number for any orthogonal square of this kind. The situation is different if g is not a prime number.

So far the explicit solution of the following problem has been derived: The 25 measurements of a quantity y obtained according to a 5 by 5 square are to be represented by a power series [Eq. (2.1)] which contains the linear terms in six variables and the second-order terms (including interaction terms) in four variables. The procedure is described in detail in the following sections.

It is believed that the great majority of practical problems will be covered by this case. A problem involving more variables or a higher order will, in general, require a greater number of measurements than desirable in a single set. Usually, division into several smaller problems will be preferable. However, the method of symmetric squares can also be applied to more complicated problems.

(4) Preplanning a Symmetric 5 by 5 Square

The advantages offered by a symmetric square can be obtained only by strict preplanning according to the following rules.

(a) As far as possible in view of theoretical and previous experimental knowledge, the independent variables z_1, z_2, z_3, and z_4 should be chosen in such a manner that the measured quantity y is in *first approximation* linearly dependent on them. The quadratic function resulting from the measurements will be a *second* approximation in any case, but the quality of the approximation depends on the selection of the variables.

(b) Two more independent variables, z_r (row coordinate) and z_0 (column coordinate), can be introduced. For these, only first-order coefficients will be determined. Variables can be introduced as z_r or z_0 if it is expected that y depends on them strictly linearly or if their influence on y is small. The subscripts r, 0, 1, 2, 3, 4 in the formulas following later must not be interchanged.

Table 5. Calculation of Coefficients

Subscripts: m = r, 0, 1, 2, 3, 4; h, i, j, k = 1, 2, 3, 4

Calculate $S(y)$, $S(x_m y)$, $S(x_j^2 y)$, $S(x_j x_k y)$ using Table 4

$E_{jj} = S[(x_j^2 - 2)y] = S(x_j^2 y) - 2S(y)$

$E_{jk} = S(x_j x_k y)$ (only for $j \neq k$)

The coefficients are:

$c_m = 0.02S(x_m y)$

$c_{hi} = S_{jk}(U_{hi,jk} E_{jk})$ (see Table 6)

$c = 0.04S(y) - 2S_h(c_{hh})$

(c) Choose the range of each independent variable z_i. Calculate the value w_i in the center of the range of z_i. One-fourth of the difference between the upper and the lower limit of the range is the distance d_i between two levels. Write down the five selected values of z_i—namely, $w_i - 2d_i$, $w_i - d_i$, w_i, $w_i + d_i$, $w_i + 2d_i$, together with the corresponding values -2, -1, 0, 1, 2 of the variable x_i. Assemble the results for all variables in a table similar to Table 2. The table thus obtained will be called Table A.

(d) The arrangement of the measurements is prescribed by Table 3 or the first seven columns of Table 4. Copy these seven columns and add in six more columns the corresponding values of z_r, z_0, z_1, . . ., z_4. Table B thus obtained is used for the experimental work.

(5) Calculation

The object of the calculation is the determination of the 17 coefficients in the power series.

$$Y = f + f_r z_r + f_0 z_0 + f_1 z_1 + \ldots + f_4 z_4 + f_{11} z_1^2 + \ldots + f_{44} z_4^2 + f_{12} z_1 z_2 + \ldots + f_{34} z_3 z_4 \quad (5.1)$$

This function Y should be determined in such a manner that it approaches the experimental results y as closely as possible.

We shall first determine the corresponding coefficients of the reduced series

$$Y = c + c_r x_r + c_0 x_0 + c_1 x_1 + \ldots + c_{11} x_1^2 + \ldots + c_{12} x_1 x_2 + \ldots \quad (5.2)$$

and later compute the coefficients of Eq. (5.1) from those of Eq. (5.2).

The subscript m will be used to indicate all coordinates including x_r and x_0; the subscripts h, i, j, k will represent only 1, 2, 3, or 4. The symbol S prescribes that the quantity following in parentheses is to be summed over all 25 experimental data. The symbols S_j and S_{jk} indicate summation over all values of the subscripts.

The computation of the reduced coefficients c is outlined in Tables 5 and 6. The formulas have been derived by the method of least squares under the assumption that equal weight may be assigned to all data. Later, the insignificant coefficients will be dropped and the standard error will be computed. The detailed procedure follows.

(a) If some of the measurements have been carried out at a level of a variable z_m slightly different from the prescribed level, an appropriate correction can be determined. The procedure, illustrated in Section 7, is not difficult but increases the computation work.

(b) Multiply each of the 25 values of y in turn by the corresponding value of y, x_r, x_0, and the other quantities appearing in Table 4. Add all 25 values of y, y^2, and of each product. The sums are called $S(y)$, $S(y^2)$, $S(x_m y)$, and

$$E_{jj} = S[(x_j^2 - 2)y] \quad (5.3)$$

Table 6. MATRIX $10^7 U$

hi / jk	11	22	33	44	12	13	14	23	24	34
11	219498	-28502	-28502	19498	10212	58212	76887	-107113	-61788	-29788
22	-28502	219498	19498	-28502	58212	-29788	-107113	76887	10212	-61788
33	-28502	19498	219498	-28502	-61788	10212	-107113	76887	-29788	58212
44	19498	-28502	-28502	219498	-29788	-61788	76887	-107113	58212	10212
12	10212	58212	-61788	-29788	187987	-20013	-37145	26855	-20013	-92013
13	58212	-29788	10212	-61788	-20013	187987	26855	-37145	-92013	-20013
14	76887	-107113	-107113	76887	-37145	26855	278122	-193878	26855	-37145
23	-107113	76887	76887	-107113	26855	-37145	-193878	278122	-37145	26855
24	-61788	10212	-29788	58212	-20013	-92013	26855	-37145	187987	-20013
34	-29788	-61788	58212	10212	-92013	-20013	-37145	26855	-20013	187987

Table 7. CALCULATION OF COEFFICIENTS

(if all interaction terms are negligible)

$c_m = 0.02S(x_m y)$

$c_{hh} = E_{hh}/70$

$c = 0.04S(y) - 2S_h(c_{hh})$

$$E_{jk} = S(x_j x_k y) \qquad (\text{for } j \neq k) \qquad (5.4)$$

(c) The further procedure is summarized in Table 5. First the linear coefficients

$$c_m = 0.02S(x_m y) \qquad (5.5)$$

are computed.

(d) The results for E_{jj} and E_{jk} are written as Table C in one column in the order prescribed by the first column of Table 6.

The second-order coefficients are calculated by the relation

$$c_{hi} = S_{jk}(U_{hijk} E_{jk}) \qquad (5.6)$$

with the aid of the matrix components U_{hijk} given in Table 6. Multiply each figure of the column headed 11 in Table 6 by the value of E_{jk} in the corresponding line of Table C, sum the ten products, and divide by 10^7. The result is C_{11}. Then multiply the column headed 22 with Table C and obtain c_{22} as the sum of the ten products. In this way proceed until all coefficients are calculated.

(e) Compute

$$c = 0.04S(y) - 2S_h(c_{hh}) \qquad (5.7)$$

from the results obtained in steps (b) and (d). Assemble all 17 coefficients in Table D.

(f) The calculation is, in principle, completed if the reduced coefficients c, c_m, c_{jj}, c_{jk} assembled in Table D are transformed into the coefficients f, f_m, f_{jj}, f_{jk} of Eq (5.1). The formulas for this transformation are

$$f = c - S_m(c_m w_m/d_m) + S_j(c_{jj} w_j^2/d_j^2) + S_{jk}(c_{jk} w_j w_k/d_j d_k) \qquad (5.8)$$

$$f_r = c_r/d_r; \qquad f_0 = c_0/d_0 \qquad (5.9)$$

$$f_j = [c_j - 2c_{jj} w_j/d_j - S_k(c_{jk} w_k/d_k)]/d_j \qquad (j \neq k) \qquad (5.10)$$

$$f_{jj} = c_{jj}/d_j^2; \qquad f_{jk} = c_{jk}/d_j d_k \qquad (5.11)$$

These equations can be checked by introducing Eq. (5.4) and Eqs. (5.9) to (5.11) into Eq. (5.1) and comparing the result with Eq. (5.2).

It is preferable, however, to postpone this transformation until the results obtained have been appropriately discussed. The discussion is based on the coefficients c, . . . rather than on the coefficients f, ...

(6) Discussion of the Results

The reduced coefficients c, . . ., assembled in Table D, furnish a comprehensive and convenient description of the experimental results. The influence of each variable and each term of Eq. (5.2) can be directly judged from the values of these coefficients. In the whole experimental range, any term $c_m x_m$ makes contributions lying between $-2c_m$ and $2c_m$ to the result, any term $c_{hh} x_h^2$ contributions between zero and $4c_{hh}$, any term $c_{hi} x_h x_i$ contributions between $-4c_{hi}$ and $4c_{hi}$. Comparison of the coefficients indicates immediately which variables and which terms are more important than the others.

In general, some of the terms will be smaller than the experimental errors. They should be eliminated since they add an unnecessary load in the application of the results. Various methods can be used for this elimination.

An extremely simple elimination procedure can be used if the magnitude of the *experimental errors* is fairly well *known in advance*. In this case, all those terms are dropped which contribute not appreciably more than the expected experimental error. If all interaction coefficients are dropped, new coefficients are easily calculated according to Table 7. The resulting new set of coefficients furnishes the best representation of the data.

If not all interaction coefficients can be eliminated, the calculation of a new set of coefficients is hardly worth while. It will be sufficient, in general, to recalculate only the coefficient c

$$c = 0.04S(y) - 2S_h(c_{hh}) \qquad (6.1)$$

Table 8. VARIANCE

$$S\left[(y - Y)^2\right] = S(y^2) - 0.04\left[S(y)\right]^2 - 50S_m(c_m^2) - 70S_h(c_{hh}^2) - 100S_{hi}(c_{hi}^2)$$
$$- 60(c_{11}c_{23} + c_{12}c_{13} + c_{11}c_{24} + c_{12}c_{14} + c_{22}c_{14} + c_{12}c_{24} + c_{22}c_{34} + c_{23}c_{24}$$
$$+ c_{33}c_{12} + c_{13}c_{23} + c_{33}c_{14} + c_{13}c_{34} + c_{44}c_{13} + c_{14}c_{34} + c_{44}c_{23} + c_{24}c_{34})$$
$$- 20(c_{11}c_{34} + c_{13}c_{14} + c_{22}c_{13} + c_{12}c_{23} + c_{33}c_{24} + c_{23}c_{34} + c_{44}c_{12} + c_{14}c_{24})$$
$$- 100(c_{12}c_{34} + c_{13}c_{24} + c_{14}c_{23})$$

Table 9. LEVELS OF THE VARIABLES (TABLE A)

x_i	-2	-1	0	1	2	w_i	d_i
speed (r.p.m.)	46	54	63	73	85		
z_1 = log speed	1.663	1.732	1.799	1.863	1.929	1.797	0.0665
Dz_1	0.001	-0.0015	-0.002	0.0005	0.001		
weight fraction oil	1/3	1/7.2	1/17.3	1/41.5	1/100		
z_2 = log (wt. fr. oil)	-0.477	-0.857	-1.238	-1.618	-2.000	-1.238	-0.381
z_3 = A/(A + B)	0	0.25	0.5	0.75	1	0.5	0.25
z_4 = feed rate (in. per revolution)	0.0030	0.0081	0.0130	0.0180	0.0230	0.0130	0.0050
Dz_4	0	-0.0001	0	0	0		

with the retained coefficients c_{hh}. In the present series of second degree, the original values of the first-order coefficients c_m are strictly the final values in any case, even if some coefficients are dropped. The second-order coefficients c_{hh} and c_{hi} are, after elimination without recalculation, not strictly the best values but in general they will furnish a sufficient approximation.

If the experimental errors *cannot* be sufficiently well *estimated in advance*, the standard deviation T of the complete series in Eq. (5.2) can be used as an estimate. The standard deviation is given by

$$T^2 = S[(y - Y)^2]/(25 - q) \qquad (6.2)$$

where q is the number of coefficients (including c) used in Eq. (6.2). The standard deviation can be used by computing all 25 "calculated" values Y according to Eq. (6.2) or with the aid of the formula given in Table 8. This formula and Eq. (6.2) are to be used only for the original complete set of coefficients or for a recalculated new set but not for coefficients retained after elimination without recalculation.

The elimination of insignificant coefficients can then be carried out as before or by comparing variances calculated for several sets of coefficients with the aid of Fisher's Table.*

The finally adopted set of coefficients c, c_m, c_{hh}, c_{hi} is directly used for the interpretation of the experimental results. For practical applications, the final set is converted to the coefficients f, f_m, f_{hh}, f_{hi} by means of Eqs. (5.8) to (5.11), as described in the preceding Section.

(7) Example—Performance of Cutting Tools

The present method has been applied in a current examination of the influence of cutting oils on the performance of cutting tools by S. J. Beaubien and L. P.

* Cf. Snedecor, G. W., *Statistical Methods*, 4th Ed., Table 10.7, The Iowa State College Press.

Table 10. Experimental Results

No.	Dy	Temp. °F=y
1		1075
2	1	1136
3	1	1051
4	-1	499
5	-6	789
6	-4	1046
7	1	876
8	-1	1061
9	-1	1089
10		580
11	1	486
12	-6	684
13	-1	1059
14		1100
15	1	1161
16	-1	1049
17	-1	509
18	-5	995
19	1	1077
20	1	1023
21	-1	1064
22		1130
23	1	611
24	-4	696
25	-1	1014

Table 11. Table of Sums (Table C)

$S(y)$	22,860
$S(y^2)$	22,166,129
$S(x_r y)$	-69
$S(x_0 y)$	-180
$S(x_1 y)$	2,371
$S(x_2 y)$	342
$S(x_3 y)$	-467
$S(x_4 y)$	6,720
E_{11}	119
E_{22}	24
E_{33}	49
E_{44}	-3,466
E_{12}	139
E_{13}	-1,101
E_{14}	-806
E_{23}	-2,296
E_{24}	-491
E_{34}	509

Richardson, Fuels and Lubricants Engineering Department, Shell Development Company.

The specific problem was to find out the relative advantages of two types of cutting oil and their mixtures. Several factors could be expected to influence the performance of the cutting tool. In the present problem, the influence of the ratio oil/water, the lathe speed (r.p.m.), and the feed rate (inches per revolution) was considered to be interesting. The tool performance, therefore, was to be tested as a function of the mixing ratio oil A/oil B and three additional independent variables.

Several quantities were selected for the description of the performance. The total force applied, the shear force, the temperature at the tool contact point, and the width of the chip were directly measured. Various other quantities were calculated from these data. In the following, the results for the tool temperature y(°F.) will be discussed.

A discussion of the possible influence of the variables on the measured quantities led to the choice of the logarithm of the speed, the logarithm of the weight fraction oil/(oil + water), and the weight fraction oil A/(oil A + oil B) as variables. The test conditions and variables are given in Table 9, which represents an example of Table A mentioned in Section 4.

Since speed and feed rate are set by means of gears provided on the lathe, the levels for z_1 and z_4 could not be selected precisely equidistant from one another. Table 9 shows as Dz_1 and Dz_4 the differences between equidistant levels with the chosen values of w_1, d_1 and w_4, d_4 and the actually used levels.

The calculation was carried out as outlined in Section 4. Since the levels of the first and fourth variables were not precisely equidistant, corrections Dy for the observed results were estimated as prescribed in paragraph (a) of Section 4. For this purpose, the average of y for the five tests in which x_4 had the value -2 was calculated. Similarly, the averages for $x_4 = -1, 0, 1, 2$ were computed. The five averages were plotted against z_4 and Δy estimated from the curve. The same procedure was followed regarding x_1. Table 10 shows the corrections and the corrected experimental results.

The results of step (b) are assembled in Table 11 (Table C). Steps (c), (d), and (e) lead to Table 12 (Table D).

These calculations can be carried out rapidly with the aid of machines such as International Business Machines as soon as the necessary master cards have been prepared. All quantities recorded in Table 11 except $S(y^2)$ can be calculated by means of sorter and tabulator. A calculating punch is used for computing $S(y^2)$ and c_{hh} and c_{hi}.

There are various means available for estimating the magnitude of the experimental errors and the significance of the coefficients assembled in Table 12.

The table contains values for the coefficients c_r and c_0 although the corresponding variables x_r and x_0, provided for in the square, have not been used. Therefore, under ideal conditions these coefficients would be zero. Deviations from zero may be due to experimental errors and to failure of the quadratic function to represent the measured quantities. Practically, the values of c_r and c_0, multiplied by two, furnish estimates of the experimental error. These estimates are, indeed, of the order of magnitude of the precision P of the instruments used in the measurements. The estimated values of P are shown in Table 12. It has been expected that the limits of accuracy of the data will be appreciably wider than the precision.

Indeed, the standard deviation T of y, calculated according to Eq. (6.2) and the formula of Table 8, is con-

Table 12. Complete Set of Coefficients (Table D)

c_T	-1.38
c_0	-3.60
c_1	47.42
c_2	6.84
c_3	-9.34
c_4	134.00
c_{11}	16.07
c_{22}	1.58
c_{33}	4.08
c_{44}	-53.61
c_{12}	8.23
c_{13}	12.34
c_{14}	-11.10
c_{23}	-4.17
c_{24}	-15.06
c_{34}	3.22
P	20
T	53.9

siderably greater. Taking the standard deviation as a basis, one sees directly that only few of the coefficients c_h and c_{hh} and none of the interaction coefficients c_{hi} are significantly greater than the experimental error. New sets of selected coefficients c_h and c_{hh}, therefore, have been calculated according to the equations of Table 7. The variances of several such sets are easily compared. The final results are given in Table 13. The standard deviation T of the new set in Table 13 is slightly, but significantly, higher than the value of T for the complete set.

Within the limitations imposed by the range and accuracy of the measurements, the following conclusions can be drawn.

Table 13. Final Coefficients

c	1013.4
c_1	47.4
c_4	134.0
c_{44}	-49.5
T	62.1
f	-951
f_1	713
f_4	$78.3 \cdot 10^3$
f_{44}	$-1981 \cdot 10^3$

(a) Cutting oil A, oil B, and their mixtures do not differ in the effect on tool temperature.

(b) The variation of the ratio of oil to water between 0.01 and 0.3 has no effect on the temperature.

(c) The tool temperature depends greatly on the feed rate and slightly, but significantly, on the speed.

The quantitative relations are given by

$$y = f + f_1 z_1 + f_4 z_4 + f_{44} z_4^2 \qquad (7.1)$$

where the coefficients are given in Table 13 and z_1 = log (speed in r.p.m.), and z_4 = feed rate in inches per revolution.

A simpler schedule can be adopted, of course, for future tests of a similar nature. But such a change would not have been justified without the information obtained in the present tests.

The present example shows the efficiency of the method of symmetric squares in determining, by means of a moderate amount of experimental and computing work, the influence of several independent variables on a measured quantity. The advantages of the method would be more conspicuous in the determination of quantities that depend on the independent variables in a more complicated way.

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393	Notes on the Analysis and Design of Multi-Post Stiffened Wings—D. M. Badger.	0.65	1.00

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IAS Previews

Summaries of Current Papers Accepted for IAS Publications

Integral Relations in the Linearized Theory of Wing-Body Interference

By

A. H. Flax

Cornell Aeronautica Laboratory, Inc.

The reverse-flow theorem is extended to the case of a wing mounted on a cylindrical body of any cross-sectional shape. Also, two Trefftz-plane theorems relating the total lift and rolling moment on such a body to the corresponding values for the wings are derived. Based on these results, some further general relationships between integrated lifts and moments on the wing, the body, and the combination are obtained. It is shown that the lift distribution on the wing-body combination in reverse flow is the influence function for lift of the combination. Further, it is shown that the influence function for rolling moment is the lift distribution over the combination rolling at constant angular velocity in reverse flow. It is also shown that the lift induced on the wings by a unit body angle of attack is equal to the lift induced on the body by a unit wing angle of attack in reverse flow. In lifting-line theory, slender-body theory, or for any wings having a spanwise axis of symmetry (such as rectangular or diamond wings), the need for consideration of reverse flow is eliminated, and the results assume a particularly simple form. The results are valid for subsonic or supersonic flow within the limitations of linearized theory.

Fully Plastic Rotating Disc With Large Strains

By

Melvin Zaid

Sperry Gyroscope Company

The thin rotating disc of arbitrary profile and boundary conditions is considered for a material with an arbitrary stress-strain curve. In order to investigate stresses, strains, and speeds leading to failure, a finite strain theory is used.

The concept of a strain plane is introduced, and, with it, general solutions are obtained and particularized to many specific profiles and materials. Residual stresses in one particular case are evaluated. With the aid of these solutions, it is shown that the bursting speed is dependent largely on profile shape, and examples are presented to show this relationship.

The small strain theory indicates that complete yielding of a perfectly plastic disc takes place for a speed of about 17 per cent above that for a disc at the elastic limit. The large strain theory, however, indicates that a speed of approximately 100 per cent above the elastic limit can be achieved before the disc will burst. The latter is a more realistic theory for evaluation of allowable safety factors.

A theoretical solution for bursting is checked against previously performed experimental work and agrees to within 1 per cent. Strain distributions check quite well.

Thermal Stresses in Conical Shells

By

J. H. Huth

The RAND Corporation

This paper considers the stresses in a conical shell of revolution resulting from aerodynamic pressure and thermal gradients. In particular, the results are applicable to the conical tip of a missile flying at zero angle of attack; a numerical example is given for a temperature distribution typical of a laminar boundary layer. It is concluded that, from the standpoint of eliminating high stresses, large temperature gradients both along a ray and across the shell thickness are most undesirable.

The Upwash Correction for an Oscillating Wing in a Wind Tunnel

By

Theodore R. Goodman

Cornell Aeronautical Laboratory, Inc.

The upwash correction has been calculated for an oscillating three-dimensional wing in a circular wind tunnel at incompressible speeds. The upwash is given both at the wing itself and at downstream positions where, conceivably, a tail may be located. The tunnel upwash is calculated numerically for the entire frequency range.

Please do not order Preprints of these papers at this time.
See page 60 for Preprints that are immediately available.

Review of Published Data on the Effect of Roughness on Transition from Laminar to Turbulent Flow

By

Hugh L. Dryden

National Advisory Committee for Aeronautics

A review is presented of the published data on the effect of roughness, especially single roughness elements, on transition from laminar to turbulent flow, in which an attempt is made to reanalyze and correlate the available information. The reanalysis shows that the transition Reynolds Number of a flat plate with zero pressure gradient is a function of the ratio of the height of the roughness element to the displacement thickness of the boundary layer at the element, this functional relation being a better representation of the data than a constant critical Reynolds Number of the roughness element. Other data show that the effects of roughness are similar in streams of different initial turbulence and that a plot of the ratio of transition Reynolds Number of the rough plate to that for the smooth plate against the ratio of the height of the roughness element to displacement thickness of the boundary layer at the element gives good correlation of all the data for a given shape of roughness element when transition occurs downstream from the roughness element.

At a certain value of the height-thickness ratio dependent on the stream speed, location of roughness element, and air-stream turbulence, the transition position reaches the element and remains there as the height or the stream speed is further increased.

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on Republic's F84F
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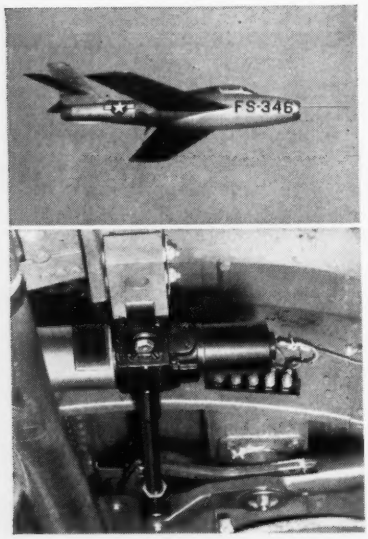

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The paper also discusses available data on the effect of distributed roughness on transition on a flat plate, as well as some of the published data on roughness effects on transition on airfoils.

Critical Bending Stress for Flat Rectangular Plates Supported Along All Edges and Elastically Restrained Against Rotation Along the Unloaded Compression Edge

By
James H. Johnson, Jr., and Robert G. Noel
North American Aviation, Inc.

A theoretical analysis of the critical bending stress for flat rectangular plates supported along all edges and elastically restrained along the unloaded compressive edge is presented. Critical buckling constants for four positions of the axis of zero stress are computed for all values of edge restraint and wave length. These four positions are locations of the axis of zero stress, varying from mid-depth of the plate to the unloaded tension edge. The latter location of the zero stress axis is that of triangular compressive loading.

A discussion of the effects of elastic restraint against rotation along the unloaded tension edge is given.

Structural Analysis and Influence Coefficients for Delta Wings

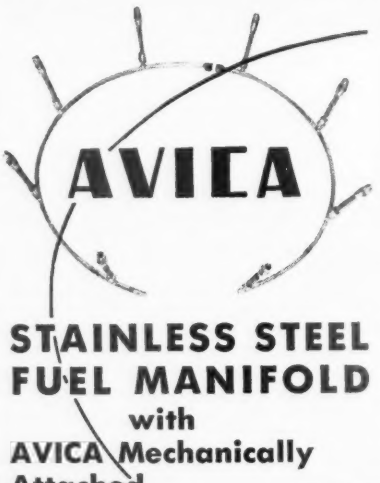
By
Samuel Levy
National Bureau of Standards

A method is presented for determining the stresses and deformations in delta wings of multispar construction having chordwise ribs and thin cover sheets. The spars need not be parallel, and the cover sheets can have large cutouts. The individual spars may be clamped, simply supported, or free at the root. The method is based on the interaction between the bending stiffnesses of the spars and ribs with effective cover sheet and the torsional stiffness of the cover sheet. The method is well suited to the use of high-speed computing machines.

Three-Dimensional Laminar Boundary-Layer Flow

By
Franklin K. Moore
Lewis Flight Propulsion Laboratory, NACA

The possibilities for predicting steady three-dimensional boundary-layer behavior are inferred from detailed consideration of the case of a cone at angle of attack to a supersonic stream.



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Qualitative features of the cone boundary layer are discussed, and solutions are presented in which: (a) Angle of attack is assumed small (a method of perturbations); thickening of the boundary layer on the lee side of the cone is indicated, but no separation of the cross flow occurs. (b) Consideration is restricted to the plane of symmetry of the flow, with no restriction on angle of attack; on the lee side of the cone, unique solutions are limited to small angle of attack, and beyond a certain angle of attack the boundary layer cannot remain thin.

The concepts of displacement thickness and flow separation are generalized to three dimensions, and failure of the thin boundary-layer assumptions is related to the formation of strong vortices in a separated region for laminar or, more tentatively, turbulent flow.

The Aerodynamic Characteristics of Low Aspect Ratio Wing-Body Combinations in Steady Subsonic Flow

By

H. R. Lawrence

Cornell Aeronautical Laboratory, Inc.

The linearized flow field about a thin wing of arbitrary twist mounted on an infinite inclined circular cylinder in a uniform incompressible free stream is formulated as the solution of a pair of simultaneous integral equations in two variables.

By making use of an extended form of the slender-body approximation, the simultaneous integral equations are shown to be equivalent to a single integral equation valid on the wing surface.

The method employed by the writer is used to approximate this two-variable integral equation by a single-variable integral equation for the chordwise lift distribution. The chordwise lift distribution on the wing-body configuration is shown to be identical with that of a wing with the same exposed plan form but altered twist distribution. A procedure for computing the distribution of lifting pressures is presented.

Methods for extending this result to bodies of finite length and to account for the effects of compressibility are discussed.

The Contribution of Higher Mode Resonance to Helicopter Rotor-Blade Bending

By

Harold Hirsch

Cornell Aeronautical Laboratory, Inc.

Results obtained from flight tests of a family of main rotor blades, similar in all respects except flapwise bending stiffness, are reviewed with the objective of pointing out the role that resonant bending, particularly in the second and third bending modes, has been observed to play in determining the beam bending moments experienced by the test blades. It has been found that in certain critical conditions the contribution of higher mode bending to the total bending moment may be as great as the sum of the steady, first and second harmonic terms usually considered in current blade analysis methods. The source of the forces exciting the resonance has not been determined; however, it appears to be of aerodynamic origin.

The results call attention to the influence resonant bending may have in determining, from the fatigue point of view, the structural life of rotor blades. Since the blade resonant frequency in the second mode will, in general, lie between four and five times rotor speed and in the third mode between six and nine times rotor speed, the number of stress cycles experienced by the rotor blades will include corresponding multiples of the rotor rotation.

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News of Members

(*Continued from page 21*)

Formerly, Junior Aeronautical Engineer, Cornell Aeronautical Laboratory, Inc.

Carvel E. Mair (TM), Engineer, Guided Missile Development, Chrysler Corporation. Formerly, Junior Engineer, Aerodynamics, Propeller Division, Curtiss-Wright Corporation.

Mrs. Helen Striho Marble (TM), Junior Aeronautical Engineer, Composite Design Section, Aero-Mechanics Department, Cornell Aeronautical Laboratory, Inc. Formerly, Junior Aeronautical Engineer, Physics Department, Cornell Aeronautical Laboratory.

Robert K. Mueller (M), Associate Professor, Department of Aeronautical Engineering, Massachusetts Institute of Technology. Formerly, Assistant Professor, Department of Aeronautical Engineering, M.I.T.

Henry E. Navert (TM), now Design Engineer "A," Flutter-Dynamics and Propeller Group, Beech Aircraft Corporation.

Flight Lieutenant A. E. Sutherland, RCAF (M), Aircraft Maintenance Officer, 3 Fighter Wing, RCAF, Zweibrücken, Germany. Formerly, Squadron Engineering Officer, 103 Rescue Unit, RCAF, Greenwood, Nova Scotia.

Edward G. Uhl (M), Vice-President-Chief Engineer, The Glenn L. Martin Company. Formerly, Chief Project Engineer, Martin.

George E. Woods-Humphrey (AF), Special Consultant to the President, Flight Refueling, Inc. Formerly, President, Flight Refueling.

Necrology

Philip R. Conrath

Philip Russell Conrath, TMIAS, Air Loads Engineer with McDonnell Aircraft Corporation, was killed in an automobile accident on August 17, 1952.

Born on July 12, 1925, in St. Louis, Mr. Conrath attended Webster Groves (Mo.) High School from 1939 to 1943. In the latter year, he enrolled at Washington University and in 1945 transferred to California Institute of Technology from which he was graduated in March of 1948 with a B.S. degree.

Immediately after his graduation, Mr. Conrath accepted a position as Junior Electrical Engineer with J. Gordon Turnbull. In June of the following year, he became an Electrical Estimator for Frank Adam Electrical Company. He joined McDonnell Aircraft Company in September, 1950, and served from then until his death in the Design-Liaison, Flight Test, Stress, and Air Loads, departments.

John D. Hubbard

Word has been received concerning the death on February 2 of John Dean Hubbard, MIAS, Assistant Project Engineer at Chance Vought Aircraft Division of United Aircraft Corporation. Further details were not given.

Mr. Hubbard was born in Oklahoma on May 15, 1917. He attended the Crescent (Okla.) High School and in 1935 matriculated at Oklahoma Agricultural and Mechanical College. He was graduated from Oklahoma A. & M. in 1939 with a B.S. degree in Mechanical Engineering, his major being in Aeronautics.

In October of 1939, Mr. Hubbard became a Junior Stress Engineer with Spartan Aircraft Company's Structures Department. The following June, he joined Chance Vought Aircraft Division of United Aircraft Corporation as Junior Stress Analyst. During his years with Chance Vought, he was responsible for the structural design and stress analysis of major components for given experimental projects, as well as of a complete production version of an entire airplane project.

John F. Jacobs, Jr.

John Francis Jacobs, Jr., MIAS, Director of Electro-Mechanical Engineering, The W. L. Maxson Corporation, died on April 3 in a New York City hospital after an illness of 3 weeks. He was 41 years of age.

Mr. Jacobs, a native of New York City, was graduated in 1932 with a B.S. degree from the United States Naval Academy. He served until 1934 as a Naval Ensign assigned to carrier aircraft operations. Upon completing this tour of duty, he resigned from the Navy and studied at Stevens Institute of Technology's Graduate School during the 1934–1935 academic year.

After working for a short time as a Junior Engineer with Fairchild Aerial Camera Corporation, he left to become Development Engineer for American District Telegraph Company. In 1940, he joined the Sperry Gyroscope Company, Division of The Sperry Corporation, as Product Engineer and was subsequently promoted to Assistant to the Chief Engineer and Assistant to the Vice-President—Research and Engineering. He was associated with Reaction Motors, Inc., from 1949 to 1951 as Engineering Manager. Two years ago, he accepted the position with the Maxson Corporation which he held at the time of his death.

Flavius E. Loudy

Flavius Earl Loudy, AFIAS, Chief Engineer in the USN Office of BuAer Representative at Grumman Aircraft Engineering Corporation, died on March 21 at Nassau Hospital, L.I., N.Y. He was 61 years of age.

Mr. Loudy was one of the pioneers in the aeronautical industry. He learned to fly in 1911 at Ann Arbor, Mich. In 1914, he developed and tested a "superior" type of flying-boat in a Navy tank. He was graduated from the University of Michigan in 1916 with a B.S.E. degree in Aeronautical Engineering.

Shortly after his graduation from Michigan, he went to work for the Martin Aeroplane Factory in Elyria, Ohio. Here, he was the Engineer-in-Charge of the design and construction of the J. V. Martin twin-engined bomber and of the Martin Kitten, a shipboard airplane that incorporated the first retractable landing gear. During 1919–1920, he had charge of the aerial torpedo experiments and transmission tests at McCook Field on the J. V. Martin bomber.

At a later period in his life, Mr. Loudy was in charge of a drafting group on the hull of the rigid airship, U.S.S. "Shenandoah," performed stress analyses of the RS-1 semirigid and TA and TC nonrigid airships, and had charge of one structural design on the rigid airship, U.S.S. "Akron." Among some of his other accomplishments was the development in 1928 and 1929 of a twin-engined five-place all-metal amphibian, done under the banner of the defunct Loudy Aircraft Company of which he was President and General Manager. He joined the Office of Naval Aircraft in 1931 and, 7 years later, was assigned to the BAR office at Grumman.

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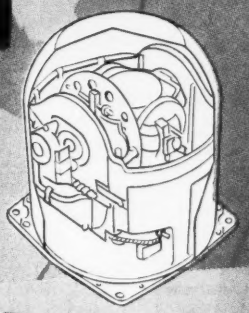
*NOVEMBER 20, 1952



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American Helicopter Society News

St. Louis Meeting

The convertiplane—built big enough for transport purposes—is "an ultimate necessity for continued expansion of commercial air transportation," in the opinion of Col. William B. Bunker, Chief, Air Transportation Services Division, U.S. Army.

Colonel Bunker expressed his point of view in an address before 150 members of the American Helicopter Society at a meeting in St. Louis on March 25. He shared the program with John I. Parcel, Vice-President of Sverdrup & Parcel, Inc., who discussed "The Professional Status of Engineers."

Colonel Bunker made it clear that, to be successful, a convertiplane will have to "offer a real measure of advantage over both the helicopter and the fixed-wing aircraft." He said that the speed would have to be at least 300 knots and that the landing requirement must not exceed a few hundred yards.

The Army, the Colonel added, will be able to use convertiplanes for observation and reconnaissance. But he doubts that they can replace helicopters and trucks for short-haul cargo service.

The speaker said helicopters themselves show great room for improvement in dependability and maintenance and the present necessity to allocate 40 per cent of available funds for spare and replacement parts, along with the necessity for storing and maintaining them, is a major military aviation problem.

Colonel William B. Bunker.

Colonel Bunker continued: "While I realize the speed advantage of the helicopter, . . . I wonder if the truck isn't still ahead. I believe it is apparent that we could afford a considerably lower pay load or less performance in the machine if we could double its availability.

"I think we can agree that the dependability of the Model T Ford was probably the cause of the success of the automobile industry. The DC-3 occupies a somewhat similar niche in fixed-wing air transportation. What we need in the rotary-wing field is an aircraft with the characteristics of these two famous vehicles."

AHS-AWA Meeting

On March 11, a joint meeting of the Aviation Writers Association and the American Helicopter Society was held at the National Press Club in Washington. The session was conducted with the Fiftieth Anniversary of Powered Flight as a background.

The speaker was B. L. Whelan, General Manager of Sikorsky Aircraft Division, United Aircraft Corporation, who told many anecdotes of his early days in aviation. Mr. Whelan is one of the few aircraft executives who completely bridges the gap between the early days of the Wright brothers and the modern helicopter industry.

Open House at Lakehurst NAS

About 250 members of the American Helicopter Society from the Philadelphia area recently attended an Open House program staged for AHS by Helicopter Squadron HU-2 at the Lakehurst (N.J.) Naval Air Station. The party was arranged by Frank K. MacMahon, of Piasecki Helicopter Corporation.

In addition to a tour of the squadron's flight and maintenance facilities, there was a demonstration of several helicopters now in service with the unit.

CLAUDE O. WITZE
Publicity Chairman, AHS

Shown during the AHS visit to the Lakehurst (N.J.) Naval Air Station are: *(left to right)* Monroe R. Brown, Treasurer, AHS; Comdr. R. S. Roberts, Commanding Officer, Helicopter Squadron Two, USN; Charles LeFever, Vice-President, AHS; and Commander McClannan, Executive Officer, Helicopter Squadron Two, USN.

Contributors to American Helicopter Society News are urged to keep in mind that it takes 6 weeks for copy to get in print. This page needs material on the activity of regional groups and individual members, but it must be in the hands of the publicity chairman not later than the 5th of the month to appear in the issue of the second month following. Address contributions to Claude O. Witze, Piasecki Helicopter Corporation, Morton, Pa.

Corporate Member News

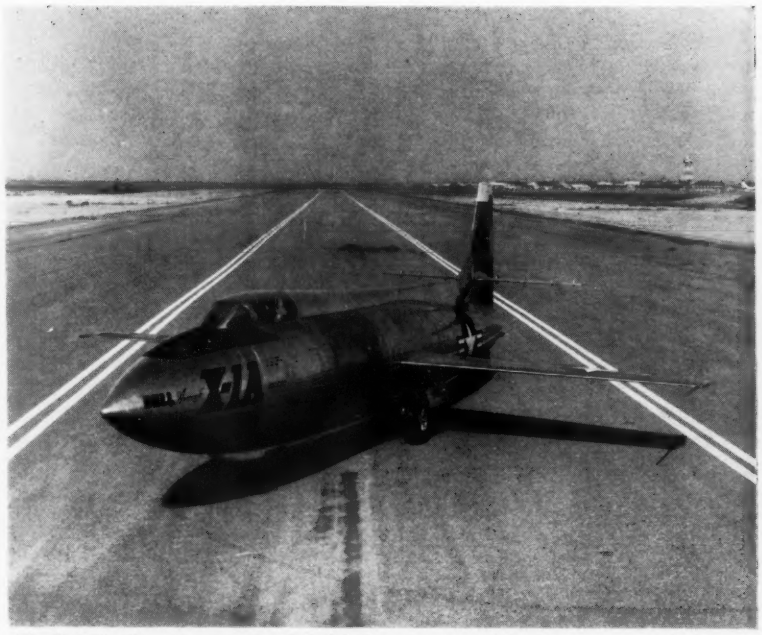
• **AiResearch Manufacturing Company, Division of The Garrett Corporation. . .** A recently developed cabin-pressure controller that is now in production at AiResearch weighs less than 3 lbs. and needs no external source of power. This unit combines a cabin-pressure selector, rate-of-change selector, and a differential pressure control; it is mounted on the pilot's instrument panel. A simple air valve for cabin-air discharge completes the system. With this cabin-pressure controller, the pilot may select cabin altitude between sea level and 10,000 ft. and any rate of change for cabin pressure between 100 and 2,000 ft. per min. The military version of this same control is available with two differentials—"cruise" and "combat.". . . A new 16-page booklet, *Electronic Facilities*, was recently published by The Garrett Corporation. This booklet, 4-0-1, covers the available facilities and activities of AiResearch and is illustrated with more than 60 pictures. It is available from AiResearch in Los Angeles.

• **Allis-Chalmers Manufacturing Company. . .** A 50-page motor and generator reference booklet, 51R7933, has been published and is intended to assist in the selection of motive power to handle most industrial applications. It is reprinted from the 1952 edition of *Lincoln's Industrial-Commercial Electrical Reference* published by the Electrical Modernization Bureau, Inc. Text and illustrations on integral horsepower motors and generators for the book were furnished by Allis-Chalmers in cooperation with the Electrical Modernization Bureau. Copies of this pamphlet, 51R7933, *Allis-Chalmers Motor and Generator Reference Book*, are available upon request.

• **Aluminum Company of America. . .** A new technique of 60-cycle induction heating which uses ordinary household electric power has been developed. This method permits the heating of a 7,700-lb. aluminum ingot to 750°F. in 50 min., as compared with some 12 hours required by conventional means such as soaking pits or other furnaces. It is said that this new technique will be invaluable in heavy-press production of big aircraft aluminum forging and extrusions. In essence, this low-cycle induction heating method consists of placing an unheated ingot in a specially designed low-frequency electrical coil. Electrical energy of commercial frequency is then applied to the coil. The flow of this current through the coil induces a heavy current in the ingot itself which in turn produces the temperature rise in the metal.

• **American Airlines, Inc. . .** James W. Aston, a Vice-President of the Republic National Bank, of Dallas, Tex., was elected a Director of American Airlines.

• **Bell Aircraft Corporation. . .** Lieutenant General William E. Kepner, USAF (Ret.), joined Bell on April 1 and 5 days later was elected by the Board of Directors to the position of Executive Vice-President. General Kepner retired from the Air Force on last February 28, after more than 40 years of active duty with the U.S. Army, Navy, Air Force, and Marine Corps. . . . J. Fred Schoellkopf, IV, has been elected to the Board of Directors to fill the vacancy created by the death of his father, J. F. Schoellkopf, Jr., on December 16, 1952. Mr. Schoellkopf is now President of Niagara Share Corporation.



The Bell X-1A, an improved and slightly larger version of the X-1 now in the Smithsonian Institution, was designed and built for the USAF by Bell Aircraft Corporation. This new research aircraft is powered by a rocket engine built by Reaction Motors, Inc. As soon as the initial flight tests are completed at the Air Force Flight Test Center, Edwards AFB, Calif., the X-1A is being turned over to the USAF Air Research and Development Command to obtain data that can be applied in the further development of America's future high-performance aircraft. The NACA will work with the USAF on the X-1A project as part of this nation's continuing research aircraft program.

• **Boeing Airplane Company. . .** A reconnaissance version of the Boeing B-47 Stratojet bomber is now being produced at the Wichita Division for the USAF. Although no details or production schedules were released, it was stated that deliveries are scheduled to start later this year.

• **Flight Refueling, Inc. . . .** At the Board of Directors meeting on April 6, Charles W. Newhall, Jr., was elected President and Treasurer of Flight Refueling, and Myron B. Gordon, AFIAS, was elected to the position of Chairman of the Board of the corporation. At the same time, George E. Woods-Humphrey was appointed Special Consultant to the President. Mr. Newhall is a Director of Flight Refueling and of Reaction Motors, Inc.; Mr. Gordon was formerly Vice-President of Fairchild Engine and Airplane Corporation and of Curtiss-Wright Corporation; and Mr. Woods-Humphrey was President of Flight Refueling.

• **General Electrical Company. . .** Funeral services for George R. Prout, G-E's Vice-President in charge of Nucleonic and Atomic Projects, were held in Schenectady, N.Y., on March 10.

• **G. M. Giannini & Company, Inc. . . .** Model 85171A Spiralpot, a slide-wire multiturn potentiometer, is now available in precision grades of ±0.05 and ±0.025 per cent linearity, with both independent and zero-based linearity ratings and closer rotational tolerances of +1°, −0°.

• **The B. F. Goodrich Company. . .** Preliminary flight tests on the first tubeless tires to be used on aircraft were completed last March at the Naval Air Test Center, Patuxent River, Md. The Grumman F9F-6 Cougar, a swept-wing Navy jet fighter, was used in the tests. The main landing tires measure 24 by 5.5 in. and are inflated to 300 lb. pressure for carrier operations. The nose-wheel tire is 18 by 5.5 in., inflated to 175 lbs.

Consolidated Vultee Aircraft Corporation's new turboprop transport seaplane, the R3Y-1 Tradewind, is shown in this artist's sketch. This 80-ton transport has a design top speed of more than 350 m.p.h. and a take-off time, with full load, of approximately 30 sec. It is powered with four Allison T40 turboprop engines, swinging contrarotating Aeroproducts propellers. A self-contained AiResearch gas-turbine starter supplies air for the pneumatic engine starter and other auxiliary systems. Built-in multicell compartmentation below the cabin floor level provides watertight integrity and also leaves the cabin free of bulkheads and other obstructions. The Tradewind has a wing span of approximately 145 ft., a length of 142 ft., 6 in., and a height at the vertical fin tip when beached in the cradle of 51 ft., 5 in. According to the present schedule, the first flight model will be launched late this summer, and the ship itself will enter transpacific Navy service early in 1954.

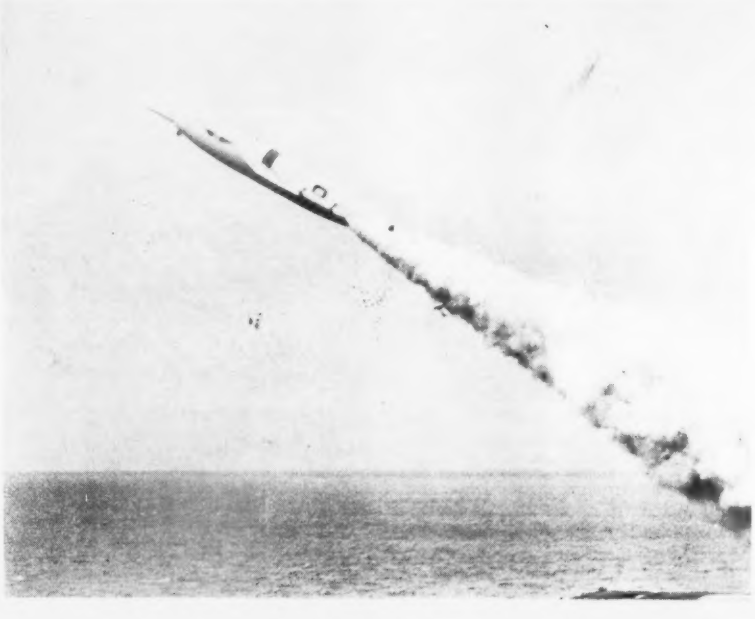
• **The Goodyear Tire & Rubber Company. . .** The Subcontract Project Sales Department at Goodyear Aircraft Corporation has been reorganized and is now able to serve manufacturers in the same way that the parent company, Goodyear Tire & Rubber, answers original equipment requirements in the automotive industry. Goodyear Aircraft has established a field representative at Seattle and realigned responsibilities of four staff representatives in the Akron, Ohio, sales office. Field representatives are also located in New York City, Wichita, Kan., and Los Angeles.

• **Johns-Manville Sales Corporation. . .** A new 32-page publication entitled *Quinterra-Quinorgo* was recently issued by Johns-Manville. It gives complete information about these electrical insulations made of purified asbestos—why they were developed, what their characteristics are, and where they may be used to advantage.

• **The M. W. Kellogg Company. . .** An industrial scholarship plan, recently announced by the company, permits salaried employees to obtain full-tuition grants for undergraduate and graduate study in accredited colleges or universities, while maintaining their regular base pay. Known as the Morris W. Kellogg Scholarships, these grants—one for study toward a master's degree and two for work leading to a bachelor's degree—are being offered annually to selected salaried employees of the company and its subsidiaries. Candidates are chosen on past scholastic achievement, experience and progress in their jobs, leadership qualities, and future potential. The first candidates under this new program were selected this spring by a management-appointed Selection Committee. . . . According to a recent announcement, the company is ceasing operations in the liquid-propellant rocket-engine field.

• **Lockheed Aircraft Corporation. . .** In order to attract more talented young Americans into engineering and industry, a Lockheed Leadership Fund has been established to finance 20 4-year college scholarships. At least 15 colleges and universities will participate in this plan. Fifteen of the 20 awards will be offered in a nation-wide competition, administered by participating schools. The remaining five will be reserved for the sons and daughters of Lockheed employees, three of these to be allotted to the California Division and the other two to the Georgia Division. The winners will be free to attend the college or university of their own selection for study in some field applicable to the aircraft industry. The participants will be free upon graduation to work wherever they choose. All of the awards will provide tuition and fees, plus $500 a year for expenses. They will be renewable each year, if the winners meet prescribed scholarship and conduct standards. In addition to the student awards, the Lockheed Leadership Fund will provide administration grants to participating colleges and universities. . . . An experimental shatter-resistant canopy, designed to protect jet-fighter pilots, has

The Regulus, a guided missile some 30 ft. in length, has been developed at the Chance Vought Aircraft Division, United Aircraft Corporation, under USN BuAer sponsorship. The program was initiated in 1947, and the first missile was developed the following year. It made its first flight in 1950 at Edwards AFB, Calif. The test and training versions of the Regulus are equipped with tricycle landing gear so that the missile may be recovered upon the completion of its flight. The missile lands on a runway of average length through the use of a parachute-type brake. In its tactical form, the Regulus has no landing gear but carries a powerful warhead. The Regulus was designed for launching from submarines, surface ships, and shore bases.



B.F.Goodrich

First Tubeless Tire for combat jets gives safer high-speed take-offs, landings

Proved in flight tests on Navy's Grumman Cougar

B. F. GOODRICH announces a new aeronautical advance—the world's first tubeless airplane tire for military jets. It's designed to give safer high-speed landings and take-offs, cut weight, simplify assembly and maintenance.

Like the famous B. F. Goodrich Tubeless Tire for passenger cars, introduced five years ago, the new airplane tire has a patented inner lining that's part of the tire itself. There's no tube to go flat—no tube to bunch up or shift during landings and take-offs.

Because the inner tube is eliminated, the new BFG tubeless airplane tire reduces overall weight of aircraft. Instead of the conventional unit of tire and matching tube, there's only one unit to assemble and mount. Only one unit to warehouse, too. In addition, there's less checking of inflation pressure because the special lining retains air much longer than conventional tubes. Loss of air around the rim is prevented by ridges molded on the outer side of the tire.

The new BFG tubeless airplane tire has passed the most severe laboratory tests, including a special "bottoming" test specified by the Navy. It showed the tire retains air even though compressed flat to the rim! The tire went on to pass its flight tests on the Grumman Cougar, new Navy jet fighter.

Another B. F. Goodrich first in aviation, the new high pressure tubeless tire for combat jets is the latest example of BFG's leadership in rubber research and engineering.

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Mail to The B. F. Goodrich Co., Dept. A-31, Akron, Ohio

completed laboratory tests and is now undergoing flight testing. This canopy, developed under the sponsorship of the USAF Air Research and Development Command, is made of two layers of plexiglass with a soft vinyl core. Pressure tightness is ensured by a rubber seal that fits the tongue-and-groove joint between the plastic and the metal. The first application by Lockheed of this new canopy is planned for the F-94C Starfire jet interceptors. . . . An experimental prototype of a "stripped-down" fighter, designated the XF-104, is to be built under contract by Lockheed. The prototype will have a straight-wing configuration; the wings, however, are to be very thin and relatively short in span. The designation of this ship, XF-104, is a reassignment of this number, its having been given previously to a Lockheed interceptor project that was cancelled in Phase I. . . . The U.S. Navy took delivery on March 11 of its first R7V-1 Super Constellation. This 106-passenger aircraft, which was assigned to the Fleet Logistic Air Wing in the Atlantic, can be converted to an all-cargo freighter or a flying ambulance.

• **Marquardt Aircraft Company. . .** A new engineering division, known as Accessories Engineering, with Robert L. Goodyear as Chief Engineer, has been established. The engineering unit that already existed has been designated Engine and Afterburner Engineering with John A. Drake, MIAS, continuing as Chief Engineer. The purpose of this move is to give a more independent status to air-borne accessories for piloted aircraft and guided missiles.

• **The Glenn L. Martin Company. . .** Two major personnel changes involve William B. Bergen, AFIAS, and Edward G. Uhl, MIAS. Mr. Bergen, who was formerly Vice-President-Chief Engineer, has assumed the post of Vice-President—Operations. Mr. Uhl succeeded Mr. Bergen as Chief Engineer and was elected a Vice-President of the company. Mr. Uhl was previously Chief Project Engineer.

• **McDonnell Aircraft Corporation. . .** Development testing of various types of jet-propulsion units used to power several types of helicopters now under development at McDonnell, began last April in the recently completed $1,200,000 propulsion test laboratory located about 1 mile east of the main McDonnell plant. In this laboratory, the air is forced through two test chambers by two compressors that can be run alternately from power provided by a 3,000-hp. motor. One of these compressors is a relatively high-pressure low-mass-flow unit, while the other one will deliver a 13½-in.-diameter jet of air at near sonic velocity. In an effort to deaden the sound, 12 in. of reinforced concrete and 4 in. of soundproof insulation plus a "sinusoidal labyrinth" type of construction was employed in the sound chambers.

• **Minneapolis - Honeywell Regulator Company. . .** A sales and service engineering office for Minneapolis-Honeywell's Aeronautical Division was opened on April 1 at 108 Cummington Street in Boston. A similar office was opened recently in Philadelphia.

• **Northrop Aircraft, Inc. . . .** A fourth noise-suppression muffler, resembling long horizontal chimneys, is now being built at the Hawthorne plant as part of the company's "Project Hush." Hollow volcanic-ash blocks are being used in its construction. In addition to the four mufflers used for ground engine operation of completed airplanes, Northrop has a fifth muffler used for quieting test runs of engines prior to their installation in aircraft.

• **Piasecki Helicopter Corporation. . .** The formation of Piasecki International Corporation as a wholly owned subsidiary of Piasecki Helicopter Corporation was announced on March 23. The new corporation, formed in Delaware, will provide service and overhaul arrangements for the parent company's helicopters in foreign countries. It will also arrange licensing for the manufacture of Piasecki helicopters and parts abroad. Directors of Piasecki International are: Frank N. Piasecki, FIAS, Chairman of the Board; Don R. Berlin, FIAS; Wesley R. Frysztacki; and Harry S. Pack. Officers of the subsidiary corporation are: Mr. Piasecki, President; Mr. Frysztacki, Vice-President and Secretary; and Gareth W. Speer, Treasurer.

• **Republic Aviation Corporation. . .** Because of Republic's growing service activity in Europe, two subsidiary companies have been created. These are Republic Aviation Corporation of France and Republic Aviation International, in Switzerland.

• **Shell Oil Company. . .** The research and fellowship programs established by Shell in 1950 will be increased by about 15 per cent for 1953–1954. This brings the total amount expended on these programs from $155,000 to $177,500. The number of fundamental research grants will increase from 12 to 14, with costs rising from $60,000 to $70,000. The number of fellowships will rise from 45 to 48, with the cost of this program increasing from $95,000 to $107,500. Research grants, of $5,000 each, are made directly to university science departments to aid them in conducting basic research in chemistry, chemical engineering, geology, mechanical engineering, metallurgy corrosion, physics, and engineering mechanics. Schools receiving fundamental research grants in 1953–1954 are: California Institute of Technology, Carnegie Institute of Technology, University of Chicago, Harvard University, Massachusetts Institute of Technology, Princeton University, University of Rochester, Stanford University, and Yale University. Except for the stipulation that the money be used directly

The chambered platform extending below the fuselage of this F-86D Sabre and somewhat forward of the wings' leading edge is the rocket firing device that was recently released by the Department of Defense from security wraps. This device is a retractable launching pod in which 24 Mighty Mouse 2.75-in. rockets are carried. Immediately after the rockets are fired, the pod snaps back into the fuselage. The F-86D is now in production at the Los Angeles plant of North American Aviation, Inc. Last November, a North American F-86D, carrying a full load of rockets, established a world's speed record of 698.5 m.p.h.

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for fundamental research in the field designated, Shell places no restrictions on publication of research results or on the way that the money is spent. The Shell Fellowship Program is designed to help outstanding graduate students obtain advanced degrees in the fields of chemistry, chemical engineering, geology, geophysics, mechanical engineering, petroleum production engineering, physics, and plant science. Shell fellows are selected by their colleges or universities; each one receives a stipend of $1,500 a year plus payment of tuition and fees. The school receives $400 for related research expenses of the fellow. Preference is given to candidates in their last year of doctorate study; however, awards may be made to other graduate students. The fellows are under no obligation to Shell. Both of the programs, research and fellowship, are administered by the Shell Fellowship Committee, made up of senior executives representing Shell Oil Company, Shell Chemical Corporation, Shell Development Company, and Shell Pipe Line Corporation.

• **Simmonds Aerocessories, Inc. . . .** Complete operation and service manuals that describe the Simmonds Pacitron fuel-gage system with which the Lockheed Super Constellation is equipped are being distributed to those air lines that will take delivery on this transport. This manual includes a large visual-aid wall chart that diagrams the entire fuel-gage system of the plane. . . . A 4-page illustrated article entitled "How to Design Push-Pull Control Systems," which appeared recently in a national trade magazine, has been reprinted and is now available from Simmonds. The data contained in the article were obtained originally from Simmonds.

• **Sperry Gyroscope Company, Division of The Sperry Corporation, and Lockheed Aircraft Corporation. . .** According to a recent announcement, two QF-80 drones, the pilotless version of the Lockheed F-80 Shooting Star, were used to fly anesthetized mice and monkeys, for biomedical purposes, through radioactive clouds resulting from the April 6 detonation of an atomic device at Yucca Flat, Nev. These aircraft were equipped with a robot control system, designed and produced by Sperry. The vital element in this system is the Sperry E-4 autopilot. The Sperry system enables "NULLO" flight by the QF-80 under direction by radio and radar from the beep-box control signals of two ground stations, worked by specially trained "beep pilots," or from nearby "director" aircraft. One of these QF-80's was guided through the radioactive cloud at a predetermined time after the detonation; the second one passed through the cloud about 2 min. later.

• **Thompson Products, Inc. . . .** At a recent meeting of the Board of Directors, Frederick C. Crawford was elected Chairman of the Board, and John David Wright was elected to succeed Mr. Crawford as President. This is the first time in the 52-year history of the company that the post of Board Chairman has been formally filled. Mr. Crawford has presided

at board meetings since he became President of the corporation after the death in 1933 of Charles E. Thompson, one of the company's founders. Prior to this double move, which is intended to meet the company's recent growth and strengthen policy and planning functions, Mr. Wright was serving as Vice-President and General Manager.

• **Vickers, Inc.** . . . Brochure *A-5206*, which describes Vickers' line of 34 standard sizes of Fixed Displacement Hydraulic Pumps, has been prepared for distribution. It is available by writing to the corporation.

• **Westinghouse Electric Corporation.** . . An 8-oz. spot heater, which keeps functioning those aircraft instruments exposed to subzero temperatures, is now available. The resistance element heater has a rating of 100 watts and operates on 28 volts d.c. Electrical connectors consist of double-nut terminals with the negative terminal grounded to the case. . . The final $50,000,000 on a $300,000,000 credit established by a group of institutional investors in November, 1951, has been borrowed. The full amount was borrowed to finance the company's expansion program and to provide necessary working capital for an increased volume of business.

IAS Sections

Atlanta Section

Edith Hall Lively, *Secretary*

The dinner meeting of February 11 was held in the Georgia Tech dining hall. Chairman George Baughman held a brief business meeting.

The evening's program was begun with the showing of a film on the Air Force Missile Test Center, Patrick AFB, Cocoa, Fla. This was followed by the main feature of the program which was a six-man panel on the subject, "New Research Developments in Aeronautical Science." The participants were: W. B. Wrigley, Dr. Richard G. Fleddermann, H. W. S. LaVier, R. P. Della-Vedowa, D. A. Webster, and D. W. Drake. Mr. Wrigley, Dr. Fleddermann, and Mr. LaVier are with Georgia Institute of Technology, while Messrs. Della-Vedowa, Webster, and Drake are with Lockheed Aircraft Corporation's Georgia Division.

Dr. Fleddermann, the first speaker, dealt with "Turbulent Flow." He touched upon its production, diffusion, and dissipation.

In Mr. Webster's discussion of "Anti-Icing Development," he told how icing can be prevented or can be melted after forming. He gave various methods used during World War II and mentioned new experiments now under way at Lockheed in California.

Mr. LaVier's subject was "Parachutes." He gave their history from 1913 through to the present time. He told of the various forms and materials which have been used and stated that Georgia Tech's Textile Department is experimenting in an effort to produce a stronger and better material for use in their construction.

Mr. Della-Vedowa added interest to the film shown earlier with his exposition on "Development in Guided Missile Work." He described the effect of high-speed flight on operational temperatures and the resulting effects of these high temperatures on various materials. A minimum of bulk with maximum strength is essential in aircraft material. Titanium is one subject for experimentation in this regard. Plastics, plastic foam, and thin ceramic coverings are proving useful.

Mr. Wrigley dealt with "Radar and Electronics" and discussed certain experiments at Georgia Tech concerning ground radar. He told of the successful development by different companies of cheaper and smaller electronic equipment for planes in the communication, navigation, and fire-control systems. He gave examples of the sizes and prices of competing manufacturers.

Mr. Drake, the final speaker, discussed "Structural Research." He cited the never-ending effort to do more with less material, which requires extensive research on new materials and new methods. He gave as an example the 15-year experimentation with titanium and various steel alloys. Computing machines, he said, greatly facilitate analysis.

An open discussion completed the evening's program.

Boston Section

E. A. McBride, *Secretary*

The March 2 meeting was held in the Measurements Laboratory Auditorium of the General Electric Company at West Lynn, Mass., and was devoted to the subject of "Helicopter Power Plants and Performance Possibilities." Approximately 175 members and guests attended the meeting.

The meeting was opened by Chairman R. L. Bisplinghoff, who introduced the speaker, Rene H. Miller, Vice-President —Engineering, Kaman Aircraft Corporation, Windsor Locks, Conn. Mr. Miller described briefly the three types of helicopters: (1) general utility; (2) crane, and (3) convertaplane. He then made some interesting comparisons of the reciprocating, gas-turbine, and ram-jet engines, giving some advantages and disadvantages of all three. In general, he indicated that the gas-turbine engine showed considerable promise despite its specific fuel consumption. For flights of longer duration the gas-turbine engine becomes competitive, has good hovering performance upon landing (less fuel weight), is compact, and can be located above passengers in commercial planes; certainly its noise level is much lower. He demonstrated the noise characteristics clearly by showing a color film of the flight tests of the gas-turbine-powered helicopter.

Following his talk, a general discussion and question period took place. At the close of the meeting, some General Electric Aircraft Data Charts were distributed, and the audience was invited to tour the Exhibit Room, containing exhibits of aircraft instruments and an accessory gas turbine. The meeting was then adjourned.

Buffalo Section

George B. Melrose, Jr., *Secretary*

Robert M. Stanley, President of the Stanley Aviation Corporation, was the guest speaker at the February 11 meeting of the Buffalo Section. His talk was entitled "Ten Years of Jet Aviation Progress." The program chairman for the meeting was Max Bleck. An attentive audience of approximately 85 members and guests was present.

The first United States jet aircraft flight took place on October 1, 1941. Since that time, many changes in aircraft and their abilities have taken place. In his address, Mr. Stanley noted many of the accomplishments attained through the use of jet engines and the major problems that currently exist. The 75 per cent increase in airplane maximum speeds is a tribute to the use of jet engines, he declared. He further stated that the reliability of turbojets is generally good—as evidenced by the increase from 3 hours to over 300 hours between engine inspections in the 10-year period. The fundamental limitation of the turbojet airplane is that it is a relatively high-altitude machine, attaining high range by flying near the service ceiling. Mr. Stanley expressed the opinion that improved fuel economy awaits metallurgical developments and that better bail-out methods must be sought. The first supersonic airplane was the rocket-powered Bell X-1. The sonic barrier, he noted, is now recognized as a figure of speech and is not a real limit to flight. The turboprop is the most promising future engine, and Mr. Stanley looks forward to its rapid development.

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The speaker closed his interesting talk with the expression of his personal point of view of the U.S. guided missile program. The goals for which we are striving are far too advanced, Mr. Stanley declared. Steady progression in small steps would be more desirable. The lengthy missile programs have resulted in the inefficient stockpiling of man power and have attracted the "long-hair" type rather than the "doer." He proposed the development of service quantities of more elementary missiles with gradual improvements to attain the Utopian design that is now being sought.

The talk was followed by a discussion period and the General Electric Company's film, *Jet Story*, which provided an appropriate ending for the meeting.

Chicago Section

Charles L. Bonnette, *Secretary*

On March 12, approximately 135 members of the Chicago Section and Student Members from the surrounding area attended a meeting at the Museum of Science and Industry in Chicago. The arrangements and the securing of the speakers were efficiently handled by the Student Members of the Aeronautical University and University of Illinois, Navy Pier Branch. Also in attendance were members of the Student branches of Illiniois Institute of Technology and University of Notre Dame.

At 6:30 p.m., a dinner was served in the Museum's cafeteria. At 7:30 p.m., the meeting was called to order by Dr. H. L. Hull, Chairman of the Chicago Section. Lyman H. Welliver, Chairman of the Student Program Committee, outlined the program for the evening and monitored the ensuing discussion. Speakers for the evening were introduced by James Piechocki, Wallace Hahn, Philip Peyer, and Ralph Flentge, all members of the Student Program Committee.

A series of technical papers was presented outlining the "Recent Design Developments" of modern-day aircraft. Each paper was highly interesting, the subject and the deliverer being as follows:

Guided Missiles—Lt. Col. F. W. Campbell, USAF, Assistant for Guided Missiles, Armament Division, Washington, D.C.

Power Plants—This paper was prepared by R. M. Hazen, Director of Engineering, Allison Division, General Motors Corporation. Because of Mr. Hazen's absence, his paper was capably presented by H. M. Broffitt, also of Allison.

Air Frames—L. M. Weeks, Chief of Stress, McDonnell Aircraft Company.

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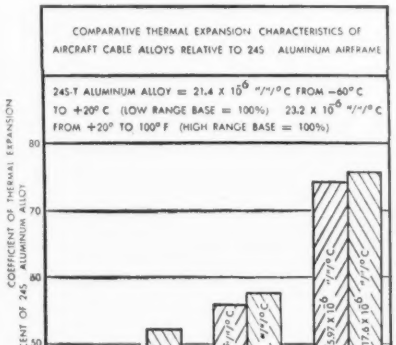
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60
50
40
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12.2 X 10⁻⁶ "/"/°C
12.1 X 10⁻⁶ "/"/°C
13.5 X 10⁻⁶ "/"/°C
15.97 X 10⁻⁶ "/"/°C
17.6 X 10⁻⁶ "/"/°C
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LOW HIGH
LOW HIGH
CABLE ALLOY — HIGH CARBON STEEL
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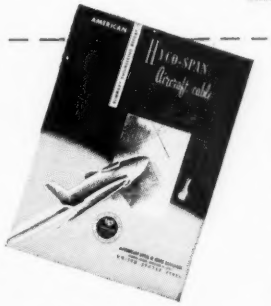

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Technical Service Data Sheet
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MIL-S-5002
AN-F-20
U. S. Navord O.S. 675
AN-C-170 (See MIL-C-5541)
U.S.A. 72-53 (See AN-F-20)
16E4 (SHIPS)

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Parts can be treated by immersion, by spraying in an industrial washing machine, by flow coating, or by brushing. This means that "Alodine" can be used anywhere, on any part or product made of aluminum. This had led to widespread use of the Alodizing process: 1. by fabricators of aluminum products in all industries to assure the utmost in product protection and finish durability; 2. by manufacturers of aluminum who are supplying Alodized aluminum sheets and coils from the mills.

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Pilot Evaluation—Col. B. S. Preston, USAF, Vice-Commander, 4706 Defense Wing, O'Hare International Airport.

The first three papers that were presented dealt with recent developments in each of the respective fields. Each paper clearly outlined the history, recent designs, and reasons for such designs and was received with intense interest by the audience. Colonel Preston, a jet pilot recently returned from Korea, then presented a pilot evaluation of each paper. Colonel Preston has flown 102 missions and is credited with destroying four MIG's and damaging four others. He depicted the pilot's point of view and opinions of the previously outlined developments.

The meeting was concluded by a panel discussion involving an active question and answer session.

Hagerstown Section

Henry F. Weisenburger, *Secretary*

The January 27 meeting, with 30 members and guests present, was held in the Terrace Restaurant, Hagerstown, Md. Chairman Henry Billings presided at the meeting. Robert Darby, Program Chairman, introduced the speaker of the evening, Raymond Young, the author of *Helicopter Engineering* who was formerly with the USN Bureau of Aeronautics and is now with Hiller Helicopters. Mr. Young's subject was "Elements of Helicopter Design."

In his lecture, Mr. Young described the history of rotary-wing aircraft through the first successful flights of the Takker in Germany in 1937 and 1939. His talk was concerned with present American manufacturers and each of their products. He then illustrated his talk with blackboard sketches of cycle pitch and methods of control, pilot's control of the aircraft, design considerations of rotors and mechanisms, practical design limits, and the future possibilities.

Two films were shown. One was on the Hiller Hornet, and the other was about the application of the helicopter in Korea. Mr. Young supplied a running commentary on the pictures.

▶ On February 24, 41 members and guests met in the Terrace Restaurant to hear Walter Tydon, Chief Engineer of the Fairchild Aircraft Division, Fairchild Engine and Airplane Corporation, present a paper on "Military Air Cargo Carrier Trends." Chairman Billings presided.

After being introduced by Program Chairman Darby, Mr. Tydon discussed operation trends as they affect component and system designs. The fuselage design, with its trend toward high

wing, is being more and more influenced by larger units of cargo. Advanced base operation, the speaker said, has also had a marked influence on cargo types with its requirements for low take-off and landing distances, low-speed stability and control, rough-field gear, simplified loading, and need for lower turn-around-time. With these have come many accepted features, Mr. Young continued, such as cockpit emergency egress hatches, external fuel with its advantages of safety, wide c.g., cargo range, ease of refueling, service and repair, and structural requirements for crash landings.

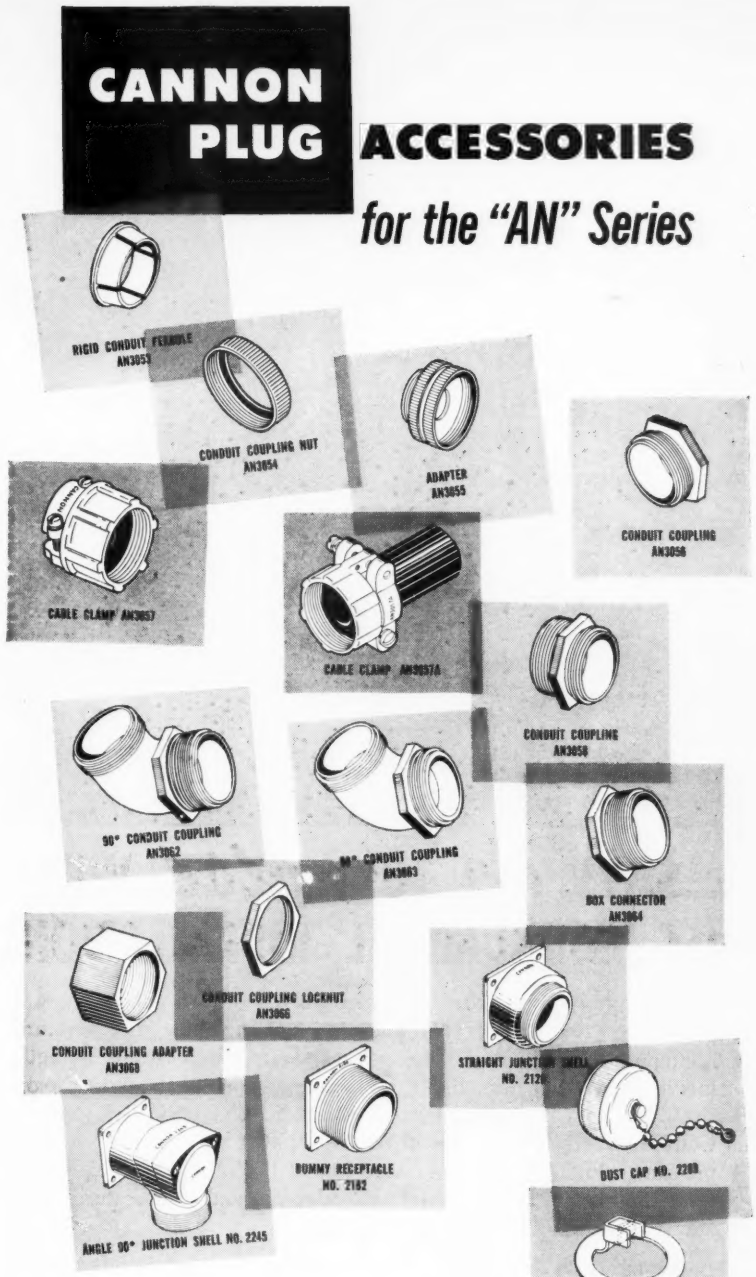
Los Angeles Section

Harold S. Fischer, *Secretary*

"Improvement of Laminated Transparent Plastics for Aircraft Glazing" was discussed by Johan Bjorksten, President, Bjorksten Research Laboratories, Madison, Wis., at a Specialist Meeting held on March 12 at the IAS Los Angeles building. Mr. Bjorksten discussed the development of an acrylic-silane interlayer that does not attack the base material and which remains clear under exposure to high temperature.

▶ On March 19, the monthly dinner meeting, arranged by the Los Angeles Historical Associates, featured an entertaining talk by William B. Stout, eminent pioneer in the field of aeronautics, on the subject, "Trends in Airplane Design—Are We Heading the Right Way?" Over 300 persons attended. Introduction of the speaker was performed by Comdr. G. O. Noville, USN (Ret.), who was Executive Officer on Admiral Byrd's antarctic expeditions. Among the prominent guests introduced to the audience were transoceanic fliers Ruth Elder and Frank Courtney (HA) and Brig. Gen. F. P. Lahm (Ret.), early flying student of the Wright brothers. Mr. Stout related incidents in his rich and varied experience, including his development of early airplanes for the Navy and his association with Ford Motor Company. He organized some of the early model-airplane clubs where some lessons of airplane design were learned economically. His classic advice to aircraft designers, "Simplicate and Add More Lightness," is as applicable today as when he first offered it more than 20 years ago.

▶ At a Specialist Meeting held on March 26, "Some Basic Concepts for Analyzing Dynamic Flight Test Data" were discussed by Harold Klein, Aerodynamics Engineer, Santa Monica Division, Douglas Aircraft Company, Inc. Mr. Klein discussed the problem of finding, through the use of observed data, the coefficients of the differential equations that describe a dynamic system.



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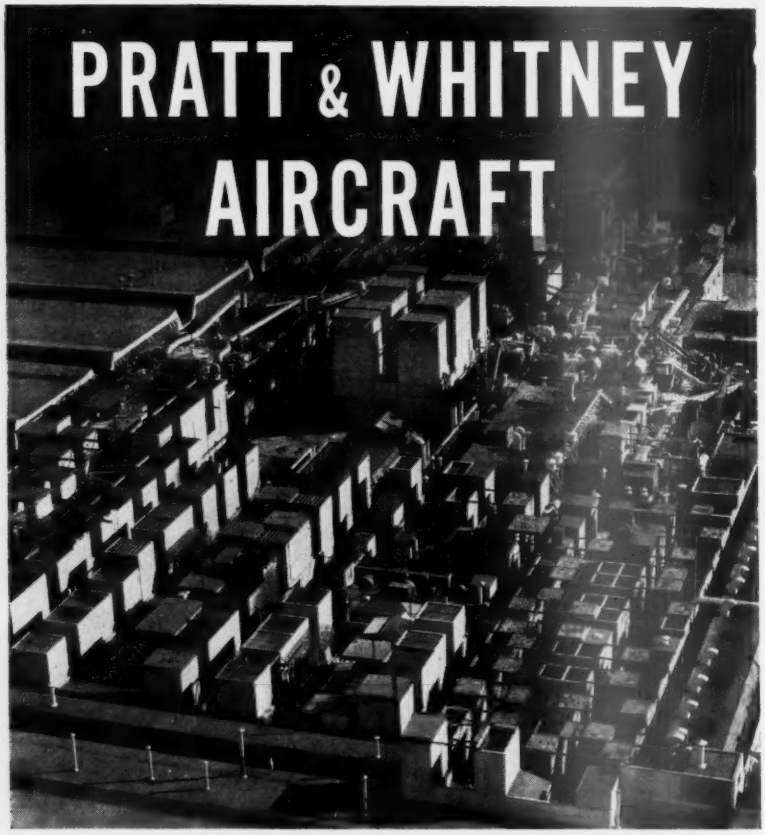

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This problem occurs in the determination of the aerodynamic stability derivatives of an airplane or missile from flight-test data.

▶ The Los Angeles Section of the IAS was a cosponsor of the Western Metal Congress and Exposition, the largest display of its kind ever held on the Pacific Coast, on March 23–27.

Montreal Section

B. J. Kaganov, *Secretary*

The meeting of March 16 was held at the RCAF 401 Fighter Squadron Mess. A. E. Ades, Assistant Director of Engineering, Trans Canada Airlines, introduced A. D. Jackson, Project Engineer, Rolls-Royce Engine Company, of England, who gave a talk on the Dart turboprop engine.

Mr. Jackson described the early pitfalls in the development and historically traced through the design of the engine. His talk was augmented with slides showing sectional breakdowns and assembly drawings of the engine. Since this engine is the first turboprop in actual service with a commercial air line, the talk was of prime interest to the gathering of approximately 75 engineers who represented airplane and engine manufacturers and air lines. The Dart powers the Vickers Viscount used by British European Airways and will soon be in service with TCA.

The speaker was thanked by E. H. Higgins, Sectional Chairman. Mr. Higgins announced that the April meeting will be cosponsored by the local Sections of the SAE and IAS. It will be a dinner meeting and will have as guest speaker, Air Vice-Marshall Miller, Vice-Chief of Staff, Royal Canadian Air Force.

New York Section

Charles Tilgner, Jr.
Secretary-Treasurer

In spite of the normal rainy weather, 85 members attended the April 7 joint meeting of the New York Sections of the IAS and IRE. The meeting was held at the Engineering Societies Building in New York.

Program chairman Bartlett opened the meeting and introduced Capt. Arthur F. Van Dyck, USNR, Staff Assistant to the Vice-President and Technical Director, Radio Corporation of America. Captain Van Dyck spoke on "Some Practical Problems in Aviation Electronics." Throughout his talk, he emphasized the need for greater reliability. He listed several possibilities for improving future designs and also made some detail suggestions. He closed with the warning that, regardless of anything else, we must have progress.

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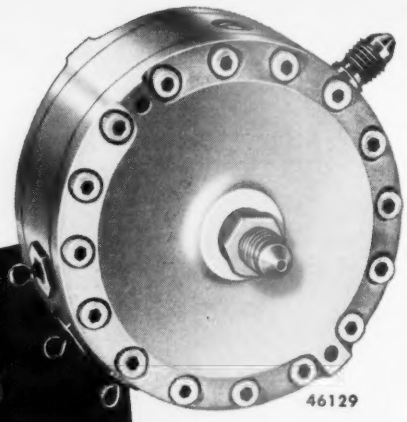

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Colonel Norman L. Winter, USAFR, Manager of Air Force Contracts for Sperry Gyroscope Company, Division of The Sperry Corporation, was introduced next. His topic was "The Common System of Air Traffic Control and Navigation," and he explained that most of what he would cover was included in a book recently issued by the Radio Technical Committee for Aeronautics. Rapid progress has been made since World War II, and, while this is only a transition system, the ultimate system is now in the hands of the Air Navigation Board.

After a brief question and answer period, the meeting closed with thanks to the speakers and the committee.

Seattle Section

Alvin J. Jarvis, *Secretary*

The February 19 meeting of the Seattle Section was held at the Sand Point Naval Air Station. Approximately 70 members and guests turned out to hear an interesting informal discussion on helicopter design problems.

Beginning his talk with a historical sketch of helicopter development, Dr. Hohenemser, guest speaker, progressed to the inherent problems of stability and resonance. Dr. Hohenemser indicated the stage of helicopter development as compared to fixed-wing design by pointing out the multiplicity of helicopter configurations as compared to fixed-wing configurations.

The advantages and disadvantages of single and multirotor, of side-by-side outrigger and intermeshing, of coaxial and tandem designs were discussed at some length with reference to the control problems involved.

Dr. Hohenemser, born in Berlin, Germany, obtained his M.S. degree in Mechanical Engineering and his Ph.D. in Mathematics and Science in Darmstadt. He worked with Ludwig Prandtl in Göttingen and as Aeronautical Engineer and Consultant to the Fiesler Aircraft Corporation in Kassel and the Flettner Aircraft Corporation in Berlin before coming to this country. From 1947 to the present, he has been Chief of Aerodynamics, Helicopter Division, McDonnell Aircraft Corporation, St. Louis.

Dr. Hohenemser punctuated the discussion with his dry humor, drawing on his extensive rotary-wing background.

After the discussion, a Shell Oil Company film, *History of the Helicopter*, was shown. The program finished with questions from the audience which Dr. Hohenemser answered.

The meeting was further honored by the presence of Capt. Cecil Gill, Commanding Officer, Sand Point Naval Air Station, who took an active part in the questioning with respect to the future of military helicopters.

Texas Section

Howard F. Marx, *Secretary*

Clifton Younie, Chief Engineer, Braniff International Airways, spoke on "Air-Line Operation" at the February 19 meeting of the Texas Section. He brought into sharp contrast the roles of the aircraft manufacturer and the air-line operator. The former may sell many types of aircraft and aircraft products; the latter has only one item to sell—service.

The Engineering Department of an air line is charged with the responsibility of ensuring that all aircraft are safe for flight. It must perform two types of maintenance functions, line maintenance and overhaul. Braniff's maintenance crews from Chicago to Buenos Aires perform routine checks and trouble shooting in the field. The overhaul personnel repair faulty units sent in by line-maintenance units and accomplish major airplane overhauls and modifications. All aircraft must be completely overhauled every 10,000 to 15,000 hours (3 to 4 years). This may be done in a single operation or in a series of operations so that the airplane and all its components are placed in "as new" condition in every 10,000-hour cycle. In addition to maintenance, the Engineering Department installs passenger-comfort items and new navigational equipment, provides loading and engine-power information for operating personnel, maintains liaison between the air line and the CAA relative to Government safety provisions.

"The trouble occurs in trying to fly large aircraft designed for large airfields into small airfields," said Mr. Younie. He described the problem Braniff faced in operating four-engined DC-4 airplanes from La Paz, Bolivia. Because all aircraft flying to Buenos Aires have to land and take off from La Paz, which is 12,500 ft. above sea level, the maximum passenger pay load over the whole route was determined by conditions existing at La Paz. Ordinary operations of twin-engined C-47 type aircraft required a reduction in pay load from a norm of 21 passengers to 11 passengers. In applying CAA safety requirements for engine failure on take-off to the faster DC-4 aircraft, Mr. Younie found that only six passengers could be carried in a four-engined aircraft.

The answer was JATO. In proof tests for the CAA at La Paz, Braniff used 16 JATO units of 200-lbs. thrust each to replace, in an emergency, the loss of thrust due to failure of one engine at the critical point in the take-off run. The successful demonstration of the emergency JATO operations enabled the thrust from all four reciprocating engines to be used in calculating the limit pay load. As a result, Braniff was able to carry 28 passengers into and out of La Paz using DC-4 aircraft. And the problem was solved!

In discussing the immediate future of jet transports, Mr. Younie stated that he believed them to be impractical for ordinary domestic flights but that his company would probably be forced to use jets for South American runs where the flying time can be reduced considerably. He predicted the future jet-transport specifications would be as follows: gross weight, 219,000 lbs.; cruising speed, 560 m.p.h.; cruising altitude, 40,000 ft.; and passenger load, 60 to 65 first class and 100 to 105 air coach.

Color films of the tests at La Paz were shown, and an informal question period was held before the meeting was adjourned.

▶ The success story of Ted R. Smith, Vice-President of Aero Design and Engineering Corporation, attracted Texas Section members in force to the March 6 dinner meeting at the Western Hills Hotel. They heard a fascinating narrative of how a group of industrious engineers—long on courage and ability but short, initially, on capital—pioneered in the design of a new type executive transport, how they financed its manufacture, and how they founded the promising Aero Design and Engineering Company of Oklahoma City.

"It was believed that most businesses during the war had learned the value of air transportation in their operations," said Mr. Smith. "They had seen and realized that this new convenience provided fast accurate transportation for their goods and personnel. . . . The basic thought at Aero Design was to provide a new airplane specifically for business—an aircraft of high performance and good load-carrying ability and one that would provide the same level of safety and performance found in the DC-3."

The company started in 1944 with eight persons who were experienced in all phases of aeronautical engineering and who were determined to do something "on their own." They worked evenings, Saturdays, Sundays—whenever they had spare time. In building the prototype, production workers accepted stock in the company in payment of their services. On April 23, 1948, the prototype flew for the first time. In producing the prototype, 25,000 engineering man-hours, 20,000 production man-hours, and $125,000 were expended.

The problems of financing production, certificating the airplane, and producing it in quantity were reviewed in detail by Mr. Smith. The company now employs approximately 600 persons and produces nine Aero Commanders per month.

Before the meeting, Mr. Smith conducted several demonstration flights in the Aero Commander for officials of the Texas Section. IAS member-pilots, who took the wheel of the airplane, were favorably impressed.

Everyone agreed that Ted Smith's visit proved to be interesting, informative, and a great deal of fun.

Washington Section

Capt. Paul J. Burr, USN, *Secretary*

A meeting was held on March 3 on the subject of delta-wing research through visualization of three-dimensional flow patterns and boundary-layer-control application to aircraft. Rear Adm. Lloyd Harrison, Deputy and Assistant Chief, Navy Department, Bureau of Aeronautics, introduced the two speakers of the evening: Dr. Alexander Lippisch, Director of Collins Aeronautical Research Laboratory, and John S. Attinello, Research Division, Bureau of Aeronautics.

In his paper, Dr. Lippisch first outlined the necessity for extended research on three-dimensional flow with respect to the problems that arise in the design of modern high-speed aircraft. He pointed out that there are two different kinds of questions; the ones connected with transient flow, as for instance the transient starting and take-off, and another type of problem concerned with steady-flow conditions, especially for low aspect ratio and swept-back wings.

Dr. Lippisch showed the methods used to visualize the flow patterns on a flying model and the methods used to visualize the flow patterns in the wind tunnel. These different methods were illustrated by portions of films that were taken on the flying models, as well as in the three-dimensional smoke tunnel. He pointed out that this work was more or less a preliminary investigation of the system to be used for research and that any further work can be based on these studies.

The paper described the methods used to do such things rather than any results, since these investigations are, with respect to size and equipment, a first attempt to get certain physical information in this way.

He also showed some still pictures that were necessary to explain the methods of the investigation.

In the second paper of the evening, Mr. Attinello pointed out that the Germans had applied, during the period 1940–1945, boundary-layer and super-circulation control to five full-scale airplanes. A duplication of the most promising installation, which was accomplished on the German ARADO #232 Assault Transport, was reproduced on a small-scale airplane and was flown as a research project under a contract of the Air Branch of the Office of

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It was also pointed out that the French, primarily through the work of Poisson-Quinton, had done a considerable amount of full-scale testing of straight and swept wings with high-lift boundary-layer and supercirculation control. The main interest of the Navy lies at present in the possibilities of considerable reduction of take-off and landing speeds and of an increase in aircraft gross weights utilizing present catapult capacities. Therefore, two-fold benefit is expected—an increase in both safety and performance.

Wichita Section

Donald J. Ahrens, *Secretary*

The April 1 dinner meeting, held at Droll's English Grill, consisted of a discussion of the "Versatility of the Helicopter" by Thomas J. Harriman, Assistant Chief Engineer of the Helicopter Division of Bell Aircraft Company. His talk described the wide range of uses of the helicopter, from carrying the mail in New York City to transporting concrete mixers and men to construction projects in remote areas.

Versatility of the craft was further demonstrated by color slides of combat and rescue operations in the rugged terrain of Korea where Mr. Harriman spent several weeks as a first-hand observer of the helicopter in action. A color film showed the use of the whirlybirds in surveying and transporting personnel, equipment, and materials for the Kemano Alcoa Aluminum plant project in the Okanagan region of British Columbia.

Mr. Harriman was introduced by Charles Seibel, Chief Engineer of The Cessna Aircraft Company's Helicopter Division. The two men worked together about 10 years ago in the preliminary development of Bell Aircraft's Model 47.

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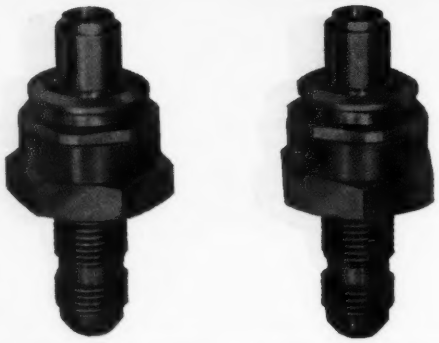

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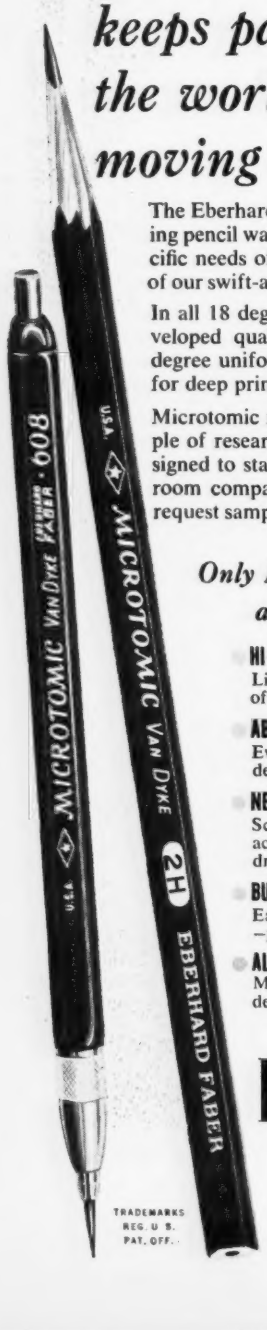

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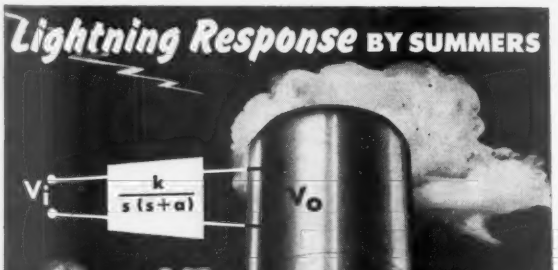

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Student Branches

Academy of Aeronautics

Kenneth O'Connor
Corresponding Secretary

On March 19, the second meeting of the spring semester was held with Chairman George Ludwig presiding. The names of those wishing to attend the First Annual Northeastern Conference at Rensselaer Polytechnic Institute were taken. Richard Kita was appointed to prepare and present a student paper at this conference. The paper is to be entitled "The Application of Jet Propulsion to Helicopters." The showing of Shell Oil Company's six-part film, *How an Airplane Flies*, brought the meeting to a close.

▶ On April 2, plans for a tour of the aircraft carrier, U.S.S. "Antietam," were finalized. The arrangements were made by Mr. Coder, Senior Instructor in the Academy's Design Department. A film from Trans World Airlines, Inc., *Letter to a Pilot*, was shown.

Twenty-five student branch members made the tour of the U.S.S. "Antietam" on April 4. Lieutenant La Turno, of the Navy's Procurement Bureau, and Lieutenant Schumann, V-3 Officer aboard the Antietam, took the group on a tour of this Essex-class carrier.

The Pennsylvania State College

Frank A. Leader, *Secretary*

A regularly scheduled meeting was held on March 19 on the Penn State campus with 44 members attending. Max Schuster, Chairman, presided.

John Gaul, our Engineering Student Council Representative, stated that the Aeronautical Department of the Engineering School would use the wind tunnel, water table, and the Link-trainer as its part in the Engineering Open House to be held on May 2.

It was decided to hold the annual picnic on May 9 at Greenwood Furnace. Robert Hess and Donald Plasterer were chosen to aid Max Schuster in getting the refreshments. Thus far, the entire expense is to be taken care of by the treasury.

A field trip to Piasecki Helicopter Corporation was discussed, but no definite plans were drawn up.

Two films were then shown: *The XF-88 Voodoo* and *The Banshee*. They were similar in that they gave the design and flight characteristics of each aircraft and showed the production and testing steps used in producing them

Syracuse University

Charles E. Rogers, *Secretary*

Chairman Fred Boenig opened the meeting of March 4 with nine members and six prospective members present. The minutes of the previous meeting were read and approved.

The Treasurer reported that $122.01 had been received on the sale of a number of aircraft engines as scrap which were donated to the Student Branch by the Aeronautical Department of Syracuse University. All members aided in dismantling the obsolete engines, a task that proved fruitful experience-wise as well as financially. Two engines remain to be disposed of this semester.

A checking account has been opened for the Student Branch, withdrawals to be made by the Treasurer and the Chairman.

Brought to the attention of the members was the possibility of students' assisting in the investigation of local aircraft accidents via the Guggenheim Aviation Safety Center at Cornell University.

Chairman Boenig explained the workings of the IAS to the prospective members, all of whom joined the organization.

Professor Martin Barzelay, Head of the Aeronautical Engineering Department at Syracuse University, spoke on the aeronautical program at the university. Professor Barzelay covered the undergraduate curriculum, the graduate program, and the developments on the new buildings for the College of Engineering. He also discussed the research work that has been done at the university for NACA. A question period brought out more information after the talk.

University of Colorado

Frank Nawrocki, *Secretary*

The March 25 meeting was called to order by Chairman Cloman D. Bogart with 19 members present.

Chairman Bogart announced that Forrest Brown and Don Dowell were the two persons selected from this university to present their papers in the IAS Texas Section's First Annual Student Paper Contest.

The Banquet Committee reported that the banquet was to be held at the Aviation Country Club in Denver on the evening of April 10. The menu was posted, and it was urged that reservations be made in the near future with the Treasurer, Jim Kutkuhn.

At the conclusion of the business meeting, Allan F. Bonnalie, now Director of Training of United Air Lines' Flight Operations Department and formerly President and General Manager of Lineas Aereas Mexicanas, S.A., presented a fine talk on the history, development, and extent of LAMSA. The slides with which Mr. Bonnalie supplemented his talk showed some of the culture and living conditions in Mexico.

A film from Consolidated Vultee Aircraft Corporation depicting its experimental plane, "The Skate," was shown, and refreshments were served.

U.S. Naval Postgraduate School

William D. Harkins, *Secretary*

Total attendance at the March 19 meeting was 30, and Lt. D. M. Layton, Chairman, presided.

Dr. J. A. J. Bennett, Assistant Chief Engineer, Hiller Helicopters, spoke on "Background of Helicopter Development." Dr. Bennett mentioned early attempts to obtain vertical flight and the evolution of various configurations of helicopters and components and completed his talk with a résumé of recent helicopter developments and applications. His most interesting speculation was concerning the feasibility of using small helicopters to handle large aircraft in a manner analogous to the way small tugs handle large ships in port. By coupling and uncoupling in flight, the helicopters could place the airplanes in the heart of large cities. This would eliminate the necessity for large outlying airfields and would also decrease present transportation time between airfields and cities.

A film, *History of the Helicopter*, was also shown.

West Virginia University

Charles R. Bartlett
Corresponding Secretary

The February 18 meeting, the first of the spring term, was called together by the outgoing Chairman, David Anderson. The following members were elected to office for the new term: Chairman, James E. Shrout; Vice-Chairman, David Anderson; Recording Secretary and Treasurer, James Heavner; and Corresponding Secretary, Charles R. Bartlett. Professor Leon Z. Seltzer is the Honorary-Chairman.

Benjamin Grove and Mr. Bartlett were appointed the IAS representatives to the W.V.U. Engineering Show Committee.

An Allison film, *Harnessed Lightning*, was shown. This film depicted the advancement of aircraft engines. An informal discussion was held, and re-

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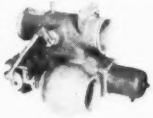

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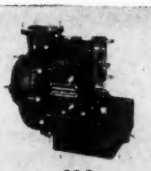

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freshments were served to the eleven attending students.

▸ Chairman James E. Shrout opened the March 4 meeting and held a short business discussion during which plans were made for the Engineering Show.

A smoke-tunnel demonstration was conducted by Professor Seltzer, Head of the Department of Aeronautical Engineering. The three-dimensional flow showing wing-tip vortices was exceedingly interesting. Twelve students were present.

▸ The March 18 meeting was opened by Chairman Shrout with ten students present. The Chairman introduced Miss Marjorie Lantz, a member of the Mountainlair Committee, who gave a talk and held a discussion on the proposed Student Union.

A business discussion followed, and the meeting was adjourned.

Members Elected

The following applicants for membership or applicants for change of previous grades have been admitted since the publication of the list in the last issue of the REVIEW.

Elected to Associate Fellow Grade

Haas, S. G. Frank, Jr., B.E. in Mech. & Elec. Engrg., Chief of Prelim. Design, Consolidated Vultee Aircraft Corp.

Schmued, Edgar, V-P in charge of Engrg., Northrop Aircraft, Inc.

Transferred to Associate Fellow Grade

Andreoli, Douglas G., Asst. Proj. Engr. F7U-3, Chance Vought Aircraft Div., United Aircraft Corp. (Dallas).

Berkowitz, Samuel M., B.S.M.E. (Aero.), Sr. Staff Engr. (Aero.), The Franklin Institute Labs. for Research & Development.

Durant, Frederick C., III, B.S. in Ch.E., Cons., Classified Proj., Arthur D. Little, Inc.

Frederick Carl Leroy, Sc.D., Pres. & Sr. Research Scientist, Frederick Research Corp.; Owner & Sr. Electronic Scientist, Carl L. Frederick & Associates; Cons., Research Directorate, USAF, WADC (Dayton).

Elected to MEMBER Grade

Beck, Theodore H., Engrg. Mgr., Fairchild Aircraft Div., Fairchild Engine & Airplane Corp. (Hagerstown).

Bernstein, Saul, B.E., Group Leader—Struct., Canadair, Ltd.

Bradley, Richard W., B.S., Capt. & Chief, Capsule Development Unit, Aircraft Lab., WADC, ARDC, USAF, Wright-Patterson AFB.

Buechel, Joseph C., B.S.E.E., Proj. Engr., General Electric Co.

Campbell Orde, Alan C., Operations Devel. Dir., British Overseas Airways Corp.

Cherry, Laurence H., B.S., Special Asst. to Dir., Guided Missiles Div., Bureau of Aeronautics, Dept. of the Navy.

Clawson, E. L., Sales & Install. Engr., Propeller Div., Curtiss-Wright Corp.

Collins, Walter S., B.S., Proj. Engr., Globe Corp., Aircraft Div.

Darsey, George E., III, B. of Sc., Aero. Field Engr., Sperry Gyroscope Co. Div., The Sperry Corp.

di Rende, Joseph S., Dr. of Engrg., Proj. Engr., Section Head, Aero. & Thermo Research & Devel. Div., Airflow Section, Wright Aero. Div., Curtiss-Wright Corp.

Fish, Edwin L., M.S. in E.E., Research Engr., Instrumentation Engrg., Flight Test Div., Lockheed Aircraft Corp. (Burbank).

Flickinger, Don, M.D., Col., USAF (MC); Dir. of Human Factors, Air Research & Devel. Command (Baltimore).

Gibson, Milford D., Proj. Engr., G. M. Giannini & Co., Inc.

Govignon, Edward C., M.S.M.E., Process Engr., Petroleum Research Div., The M. W. Kellogg Co.

Hart, George Harrison, S.M. (Math.), Engrg. Mathematician, Trans-sonics, Inc.

Kenney, James T., Jr., M.S., Proj. Engr., Sandberg-Serrell Corp. (Pasadena)

Laird, A. Wilson, V-P, Engrg., The New York Air Brake Co.

McDonald, Richard F., B.S. in Ae.E., Flight Engr., Lockheed Aircraft Corp. (Burbank).

McKelvie, John L., S.M. in E.E., Proj. Engr., Servo Design, PSC Applied Research, Ltd. (Toronto).

Neitzel, Robert E., B.S.M.E., Tech. Engr., Aircraft Gas Turbine Dept., General Electric Co.

Newton, John C., B.Sc. in Engrg., Proj. Engr., Specialties, Inc.

Phillips, Warren L., M.S., Aerodynamicist, Aerophysics Development Corp.

Rhody, Francis J., Jr., B.S. in C.E., Deputy Chief, Airport Engrg. Div., CAA (Washington, D.C.).

Roberts, Fred T., Jr., Production Design Engr., Northrop Aircraft, Inc.

Samain, Frederick A., Jr., B.S., Safety Rep., AiResearch Mfg. Co.

Schweizer, Paul A., B.S. in M.E., V-P & Gen. Mgr., Schweizer Aircraft Corp.

Seels, Henry Frank, B.S. in E.E., Field Engrg. Supt., Sperry Gyroscope Co. Div., The Sperry Corp.

Singer, Josef, D.I.C. in Aero., Capt. & Engrg. Officer, Israel Air Force.

Smith, Kenneth F., Proj. Engr., Schweizer Aircraft Corp.

Steinmetz, T. J., M.S. in M.E., Proj. Engr., Rep. at Fairchild Aircraft Corp., Kaiser-Frazer Corp.

Stockham, Henry B., B.S., Flight Test Engr., Lockheed Aircraft Corp. (Burbank).

Tiffany, Raphael J., B.S. in Education, Aero. Design Engr., Fairchild Aircraft Div., Fairchild Engine & Airplane Corp. (Hagerstown).

Wilcox, Emory C., B.Sc. in Met. Engrg., Aero. Research Scientist, Propulsion Systems, Lewis Flight Propulsion Lab., NACA.

Transferred to MEMBER Grade

Bruman, Joseph R., M.S., Sr. Proj. Engr., Jet Propulsion Lab., California Institute of Technology.

Ely, Raymond L., Dr. of Sc. in Math., Engr., Applied Physics Lab., The Johns Hopkins Univ.

Grey, Jerry, Ph.D. in Ae.E., Research Assoc., Dept. of Aero. Engrg., Princeton Univ.

Hardy, Maurice M., B.S.A.E., Stress Engr. & Designer, G. O. Noville & Associates, Inc.

Kuldell, Philip D., B.S., Proj. Engr. GS-9, David Taylor Model Basin (Washington, D.C.).

Oliver, Raymond B., M.S. in A.E., Aerodynamics Supvr., Aerophysics Lab., North American Aviation, Inc. (Downey).

Potter, Edwin F., Jr., M.S. in Ae.E., Aero. Engr., Supvr. of Aerodynamic and Weight Unit, Naval Aircraft Factory (Philadelphia).

Wellman, Roy J., Major, USAF; Directorate, Research & Devel., Aeronautics Div., DCS/D, Hq. (Pentagon).

Elected to Associate Member Grade

Arnold, H. Roys, B.S. (E.E.), Asst. Mgr., Aviation Gas Turbine Div., Westinghouse Electric Corp. (Philadelphia).

Knapp, Charles W., B.Sc., Lt. Comdr., USN; Asst. Supt., Aero. Struct. Lab., NAES (Philadelphia).

Rhoads, Homer H., Pres., Hydro-Aire, Inc.

Rich, Stuart L., Mgr., Govt. Contracts, Glowmeter Corp.

Tolson, Arthur G., A.A., Electronics Quality Control Rep., Western Air Proc. District, AMC, USAF (Los Angeles).

Elected to Technical Member Grade

Butler, Donald L., B.Sc. in Ae.E., Lt., USN; Aviator, Maint. & Ord. Officer, Sq. VF-31, U.S.S. "Leyte."

Dennis, Dwight L., Lt. (j.g.) USNR; Naval Aviator, General Line Officer, USN.

Fahey, Russell E., B. of Sc., Aircraft Designer "B," Harper Engineering Co.

Long, William R., B.S., Liaison Engr., Fairchild Aircraft Div., Fairchild Engine & Airplane Corp. (Hagerstown).

McLarin, Maitland, Sc.B.E., Asst. Product Engr., Sperry Gyroscope Co. Div., The Sperry Corp.

Meyers, William F., Power Plant Design Engr., Douglas Aircraft Co., Inc. (El Segundo).

Osmanski, Joe T., B.S., Asst. Proj. Engr., Globe Corp., Aircraft Div.

Payzer, Robert J., B.M.E., Tech. Engr., Aircraft Nuclear Propulsion Proj., General Electric Co. (Cincinnati).

Sanford, Paul E., B.S.M.E., Lt., USAF; Communications Officer, 3337th Tech. Tng. Sqdn., Scott AFB.

Schilling, Edward A., B.Sc., Group Engr., Grand Central Aircraft Co.

Scipio, L. Albert, II, Ph.D., Lecturer, Dept. of Aero. Engrg., Univ. of Minnesota.

Tennant, Samuel M., M.S.M.E., Struct. Engr., Temco Aircraft Corp. (Dallas).

Vroman, Gerald A., B.S.Ae.E., Struct. Engr., Rohr Aircraft Corp.

Young, Maurice I., M.A. (Math.), Dynamics Engr., Bell Aircraft Corp. (Ft. Worth).

Transferred to Technical Member Grade

Adornato, John A., Design Draftsman, Grumman Aircraft Engineering Corp.

Allen, Hilary W., B.S. in Ae.E., 2nd Lt., USAF.

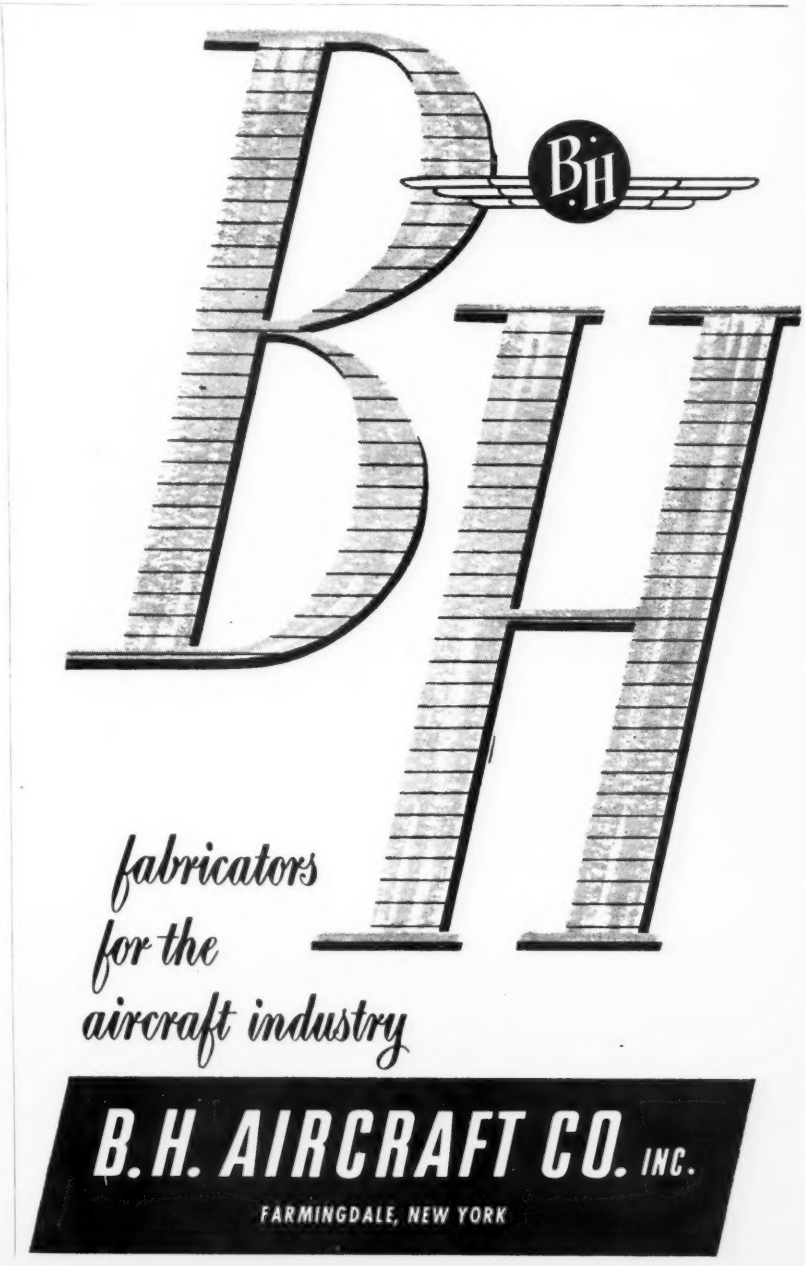
Alter, Robert L., B.S., Capt., USAF; Proj. Engr., Wright-Patterson AFB.

Balog, John, Apprentice Mechanic, Eastern Air Lines, Inc.

Beach, Robert E., Field Service Rep. "C," North American Aviation, Inc. (Los Angeles).

Bennett, Glenn Robert, Field Service Rep., North American Aviation, Inc. (Edwards AFB).

Berger, Frederick, Design Engr., Goodyear Aircraft Corp.



Blair, Emerson B., B.S., Capt., USAF; Electronics Engr.-Proj. Officer, Air Force Armament Center, Eglin AFB.

Buetow, Merrill E., B.S. in Ae.E., Jr. Engr.-Aerodynamics Unit, Boeing Airplane Co. (Seattle).

Burbick, James W., B.S. (Aero.).

Byrtus, Joseph R., B.S., Lt. Col., USAF; AMC, Wright-Patterson AFB.

Collelo, Pasco D., B.S. (Physics), 2nd Lt., USAF; assigned to Communications School, Scott AFB.

Consoli, John R., Jr. Engr.-Draftsman "B," Electrical Group, North American Aviation, Inc. (Los Angeles).

Cooper, Norman R., B.S. in Ae.E., Grad. Student & Research Engr. II, Defense Research Lab., Univ. of Texas.

DiPeri, Leonard J., B.S (Aero.), 2nd Lt., USAF; Student Officer—Pilot Training, 3306th Pilot Training Sq., Bainbridge AFB.

Donaldson, George A., B.S. (Aero.), 2nd Lt., USAF.

Erickson, Carl G., B.S.M.E., Capt., USAF; Navigator, Mather AFB.

Foster, J. Y., Design & Research Engr., Fair Play Mfg. Co.

Fox, Marvin K., B.S. in Ae.E., Field Engr., Consolidated Vultee Aircraft Corp. (Ft. Worth).

Fulton, Theodore A., B.S., Jr. Engr. "B," Boeing Airplane Co. (Seattle).

Gilnack, Ralph F., Jr.

Glass, James C., B.S. (Aero.), Jr. Engr., Power Plant Group, Douglas Aircraft Co., Inc. (Santa Monica).

Grevera, Casimier J., Stress Analyst, Fairchild Aircraft Div., Fairchild Engine & Airplane Corp.

Harold, Karl F., Jr. Engr.-Draftsman "A," Instrumentation Dept., Guided Missiles Section, Electro-Mech. Design Group, Northrop Aircraft, Inc.

Harvey, Ray W., M.S. in Ae.E., Engr., ARO, Inc.

Haynes, William B., Jr., B. of Ae.E., Design Engr., East Coast Aeronautics, Inc.

Jacob, Arthur W., Engrg. Draftsman "A," North American Aviation, Inc. (Columbus).

Jessen, Andrew R., Jr. Engr.-Draftsman "A," Northrop Aircraft, Inc.

Kipin, Peter B., B.S. in Ae.E., Struct. Engr.—Stress Analysis, Chase Aircraft Co., Inc.

Lapedes, Donald E., B.S., Jr. Test Engr., Aerodynamic Test Div., Univ. of Southern California (Pt. Mugu).

Laudeman, Ernest C., B.S., Tech. Analyst—Flight Test, McDonnell Aircraft Corp.

Le Cours, Camille A., Jr., B.S. in Ae.E., Controls Test Engr., Aviation Gas Turbine Div., Westinghouse Electric Corp.

Lewellen, James G., B.S. in Ae.E., Asst., Aero. Engrg. Dept., Parks College of Aeronautical Technology.

McCarty, Thomas A., B. of Ae.E., 2nd Lt., USAF; Attending Armament Systems School, Lowry AFB.

McGuire, R. Loren, B.S.M.E. (Aero.), Asst. Aero. Research Engr.-Technical Editor, Cornell Aeronautical Lab., Inc.

Miller, George J., B.S. in Ae.E., Design Engr., Aviation Gas Turbine Div., Westinghouse Electric Corp.

Morris, George W., B.S. in Ae.E., Aerodynamicist, McDonnell Aircraft Corp.

Negris, Vitalis.

Newgent, Jack, B.S. in Ae.E., Assoc. Engr., Struct. Group, Douglas Aircraft Co., Inc. (Long Beach).

Nold, Henry G., Jr., B.S. in Ae.E., Devel. Engr., Goodyear Aircraft Corp.

Northcott, Clyde A., Jr., Capt., USAF; Chief, Tactical Bombing Section, Air Force Armament Center, Eglin AFB.

Nothnagle, Frank C., B.S., Flight Test Instrumentation Engr., Chance Vought Aircraft Div., United Aircraft Corp.

Papadopoulos, James G., B.S. in Ae.E., Struct. Engr., Stress Analysis, Bell Aircraft Corp.

Pierce, Neil J., B.S., Engr. "C," Controls Group, McDonnell Aircraft Corp.

Quiaoit, Jesus S., B.S., Aerodynamic Engr., Fletcher Aviation Corp.

Rapstad, Harold M., Jr. Engr., Design Draftsman, Northrop Aircraft, Inc.

Reitz, David R., M.S., Grad. Student, Univ. of Michigan.

Rieben, P. Andre, B.A. (Physics), Design Engr., Hydraulic Group, Gladden Products Corp.

Robins, Harold J., Design Draftsman, Goodyear Aircraft Corp.

Rumbaugh, Don K., Struct. Testing Engr., Consolidated Vultee Aircraft Corp. (San Diego).

Ruth, John D., B.S. in Ae.E., Head, Aero. Lab., Tri-State College.

Schmetzer, William M., B.S., Assoc. Engr., Wind Tunnel Model Design, Douglas Aircraft Co., Inc. (Santa Monica).

Sellers, Cloyd W., B.S., Major, USAF; Asst. Chief, Bombing Branch, AFAC, Eglin AFB.

Sidwell, Charles Wm., Jr. Aero. Engr., The Glenn L. Martin Co.

Sowell, Roderic C., Jr. Engr. "B," Boeing Airplane Co. (Seattle).

Swope, William A., Jr. Engr.-Draftsman "A," Northrop Aircraft, Inc.

Timoshenko, Nick J., B. of Ae.E., Engr.-in-Training, A. V. Roe Canada, Ltd. (Malton).

Townsend, Terry M., Sc.B., Aero. Research Scientist, Langley Aeronautical Lab., NACA.

Weaver, Robert J., B.S. in Ae.E., Struct. Engr.—Stress Analysis, Bell Aircraft Corp.

Wells, Harold M., Jr., B.S. in Ae.E., 2nd Lt., USAF; Aero Engr.-Student, Grad. Aero. Engrg., Institute of Technology, Wright-Patterson AFB.

Wharton, Charles L., Jr., M.S. in Ae.E., Grad. Student, Georgia Inst. of Technology.

Wray, George G., B.S. in Ae.E., Missile Service Rep., Douglas Aircraft Co., Inc. (Santa Monica).

Wuerz, Al H., Jr., B.S. in Ae.E., 2nd Lt., USAF; Student Pilot, 3300th Pilot Training Sq., Graham AFB.

Yeager, Ronald E., B.S. (Aero.), 2nd Lt., USAF; Student Pilot, Graham AFB.

Attention Members!

All members of the Institute are invited to submit material concerning their activities for publication in the "News of Members" columns of the *Aeronautical Engineering Review*. Responsibility for new developments, awards or honors received, and appointments to new or additional positions are some of the items that your editors believe are of interest to other IAS members. A brief letter or postal card giving exact details will be sufficient. Photographs accompanying news items will be welcomed and will be used where practicable.

Items will be considered on the basis of their timeliness and general interest. Correspondence should be addressed to the News Editor, *Aeronautical Engineering Review*, 2 East 64th Street, New York 21, N.Y.

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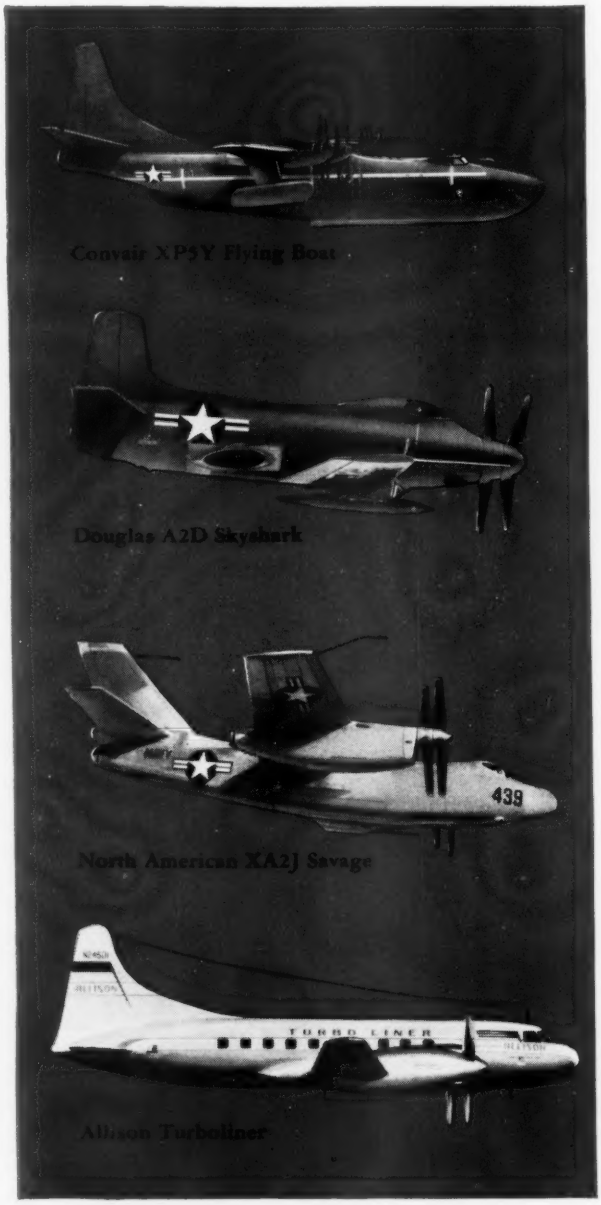

Powerful Allison Team Used in all Four U. S. Turbine-Propeller Planes

Turbine-driven propellers solve many urgent needs for truly high performing aircraft. They provide the answer to the desired combination of heavy payload, higher speed and longer range. Yet turbine engines, plus propellers, permit take-off and landing from shorter runways.

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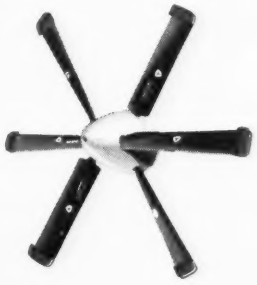
Serving with all three is America's only commercial-type turbine transport—the Allison Turboliner. Equipped with Aeroprop four-bladed propellers and Allison turboprop engines, it is General Motors' contribution to the proof-testing of turbines and propellers in a broad band of military and commercial aircraft applications.



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Aeroproducts

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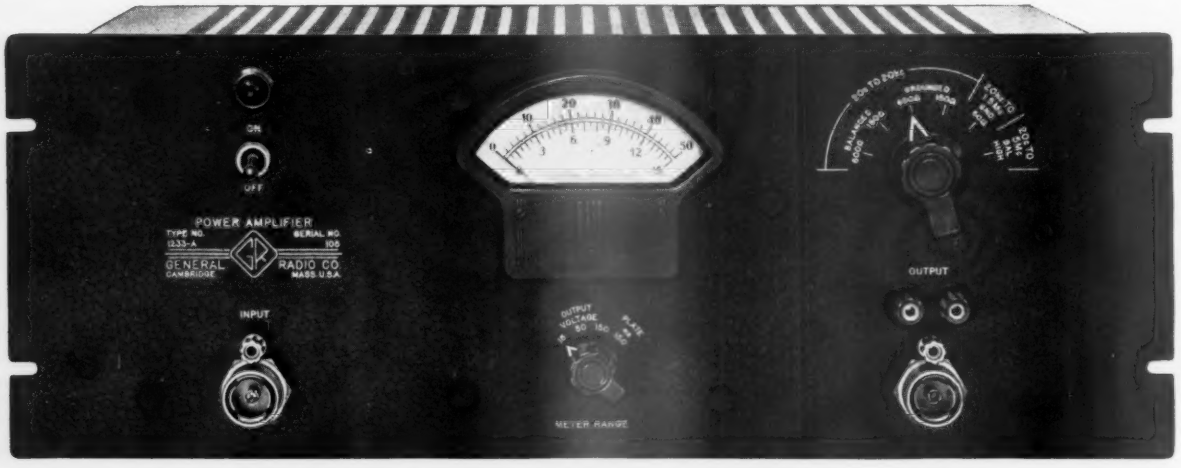
Where a reliable instrument is needed for undistorted amplification over a wide frequency range, the Type 1233-A Power Amplifier is highly recommended.



★ *Three Frequency Ranges*

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20 kc to 1.5 Mc	*50 ohms grounded*	*15 watts from 20 kc to 0.5 Mc 8 watts at 1.5 Mc*
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Variacs ☆ Light Meters ☆ Megohmmeters ☆ Motor Controls
Noise Meters ☆ Null Detectors ☆ Precision Capacitors
Pulse Generators ☆ Signal Generators ☆ Vibration Meters ☆ Stroboscopes ☆ Wave Filters
U-H-F Measuring Equipment ☆ V-T Voltmeters ☆ Wave Analyzers ☆ Polariscopes

Aeronautical Reviews

A Guide to the Current Literature of Aeronautical Research and Engineering

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Bibliographies on special subjects will be compiled at the rate of $2.50 per hour. *Translations* of technical literature from foreign languages may be obtained at $12 to $14 per 1,000 words, depending on the language. IAS members receive a 20 per cent discount on bibliographies and translations.

Full information about library membership and facilities will be sent upon request to The Paul Kollsman Lending Library, 2 East 64th St., New York 21, N. Y.

Abbreviations for Titles of Periodicals and Reports

Effective with this issue, titles of periodicals and reports cited in the Aeronautical Reviews Section are being abbreviated in order to conserve space and to expedite the flow of materials. Selection of titles in this list of abbreviations is based on materials received during the past year. Reference citations are listed in the briefest form, with only the first page given for periodicals and the total number of pages for reports and other types of publications.

Publications reviewed are filed permanently in the IAS Library. Requests for loans of materials should be directed to the Librarian, IAS Library, 2 E. 64th St., New York 21, N.Y.

A&M Coll. Tex. Eng. Exp. Sta. Res. Rep. Agricultural and Mechanical College of Texas, Texas Engineering Experiment Station, Research Report

Acta Polytechnica (Stockholm)

Aero Dig. Aero Digest

Aero. Eng. Rev. Aeronautical Engineering Review

Aero Res. TN; Bul. Aero Research Technical Notes; Bulletin

L'Aerotecnica (Rome)

Aeronautics

The Aeroplane

Aerovox Res. Worker. Aerovox Research Worker

AHS Papers. American Helicopter Society, Papers

AIAA Papers. Aircraft Industries Association of America, Papers

Air Facts

Air Force

Air Line Pilot

Air Pictorial

Air Transp. Air Transportation

Air U. Quart. Rev. Air University Quarterly Review

Airborne Instr. Lab. Proj. Rep. Airborne Instruments Laboratory, Project Report

Aircraft (Australia)

Aircraft (Canada)

Aircraft Eng. Aircraft Engineering

Aircraft Heating Dig. Aircraft Heating Digest

Aircraft Prod. Aircraft Production

Airports & Air Transp. Airports & Air Transportation

Allis-Chalmers Elec. Rev. Allis-Chalmers Electrical Review

Am. Av. American Aviation

Am. J. of Phys. American Journal of Physics

Anal. Chem. Analytical Chemistry

Antiaircraft J. Antiaircraft Journal

Appl. Hydraulics. Applied Hydraulics

Appl. Mech. Rev. Applied Mechanics Reviews

Appl. Sci. Res., Sect. A. Applied Scientific Research, Section A (Mechanics, Heat, Chemical Engineering, Mathematical Methods)

Appl. Sci. Res., Sect. B. Applied Scientific Research, Section B (Electrophysics, Acoustics, Optics, Mathematical Methods)

ASME Preprints; Papers. American Society of Mechanical Engineers, Preprints; Papers

ASTM Bul. American Society for Testing Materials, Bulletin

ATA Papers. Air Transport Association (of America), Papers

Audio Eng. Audio Engineering

Australia, Aero. Res. Consultative Comm. Rep. Australia, Department of Supply, Aeronautical Research Consultative Committee, Reports

Australia, ARL EN; Rep.; S&M Monogr.; S&M TM; Notes. Australia, Department of Supply, Aeronautical Research Laboratories, Engine Notes; Reports; Structures and Materials Monographs; Structures and Materials Technical Memorandum; other Notes

Australian J. of Appl. Sci. Australian Journal of Applied Science

Australian J. Phys. Australian Journal of Physics [formerly Australian Journal of Scientific Research, Series A (Physical Sciences)]

Auto. Ind. Automotive Industries

Av. Age. Aviation Age

Av. Week. Aviation Week

Bearing Engr. Bearing Engineer

Bee Hive

Bell Aircraft Rep. Bell Aircraft Corporation, Reports

Bell System Tech. J. Bell System Technical Journal

Bendix Av. Eng. Rep. Bendix Aviation Corporation, Engineering Reports

Boeing Mag. Boeing Magazine

Brit. J. Appl. Phys. British Journal of Applied Physics

Brown-Boveri Rev. Brown-Boveri Review

Bul. AMS. Bulletin of the American Meteorological Society

Bus. Flying. Business Flying

Canada, NAE LR; Note; Quart. Bul.; Rep. Canada, National Aeronautical Establishment, Laboratory Report; Note; Quarterly Bulletin; Report.

Canada, NRC Div. Mech. Eng. Rep. Canada, National Research Council, Division of Mechanical Engineering, Reports

Canada, RCAF, Rockcliffe, Rep. Canada, Royal Canadian Air Force, Rockcliffe, Report

Can. Airline Pilot. Canadian Airline Pilot

Can. Av. Canadian Aviation

Can. J. Phys. Canadian Journal of Physics

Can. J. Tech. Canadian Journal of Technology

CEC Recordings

Chrysler Eng. Div. Rep. Chrysler Corporation, Engineering Division, Reports

CIT Jet Propulsion Lab. Prog. Rep. California Institute of Technology, Jet Propulsion Laboratory, Progress Report

Coll. of Aeronautics, Cranfield, Rep. College of Aeronautics, Cranfield, England, Reports

Collins Signal

Commun. on Pure & Appl. Math. Communications on Pure and Applied Mathematics

Cook Res. Labs. Papers. Cook Research Laboratories, Papers

Cornell Aero. Lab. FRM; Rep.; Transl. Cornell Aeronautical Laboratory, Inc., Flight Research Memorandum; Report; Translations

Cornell U. Med. Coll. Crash Injury Res. Papers. Cornell University Medical College, Crash Injury Research Papers

Corrosion

Curtiss-Wright Corp., Wright Aero. Div., Rep. Curtiss-Wright Corporation, Wright Aeronautical Division, Report

de Havilland Gazette

Douglas Rep. Douglas Aircraft Company, Inc., Reports

Douglas Serv. Douglas Service

Elec. Commun. Electrical Communication

Elec. Eng. Electrical Engineering

Electronic Eng. Electronic Engineering

Electronics

Electronics Forum

The Engr. The Engineer

Eng. J. Engineering Journal

Engr. Dig. Engineer's Digest

Escher Wyss News

Esso Air World

Fasteners

Flight

Flight Control (**Bendix**)

Flight Mag. Flight Magazine

Flight Safety Foundation, Papers

Flying

Flying Safety (**USAF**). Flying Safety (United States Air Force)

France, Min. de l'Air BST; NT; PST. France, Ministère de l'Air, Bulletin des Services Techniques; Notes Techniques; Publications Scientifiques et Techniques

France, ONERA Pubs. France, Office National d'Études et de Recherches Aéronautiques, Publications

Franklin Inst. J. Franklin Institute Journal

Franklin Inst. Labs. TR. Franklin Institute Laboratories for Research and Development, Technical Reports

The Frontier

GALCIT Memo. Guggenheim Aeronautical Laboratory, California Institute of Technology, Pasadena, Calif., Memorandums

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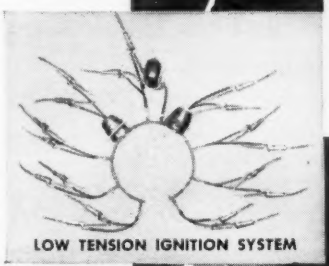

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Garbell Res. Foundation, Aero. Ser. Garbell Research Foundation, Aeronautical Series

G-E Rev. General Electric Review

Gen. Radio Exp. General Radio Experimenter

Gt. Brit., AERE Rep. Great Britain, Atomic Energy Research Establishment, Reports

Gt. Brit., ARC CP. Great Britain, Aeronautical Research Council, Current Papers

Gt. Brit., ARC R&M. Great Britain, Aeronautical Research Council, Reports & Memoranda

Gt. Brit., Meteorological Off. Prof. Notes & Reps. Great Britain, Meteorological Office, Professional Notes and Reports

Gt. Brit., NGTE Rep. Great Britain, National Gas Turbine Establishment, Reports

Gt. Brit., NPL Aerodynamics Div. Rep. Great Britain, National Physical Laboratory, Aerodynamics Division, Reports

Gt. Brit., RAE Rep. Great Britain, Royal Aircraft Establishment, Reports

Gt. Brit., RAE TN. Great Britain, Royal Aircraft Establishment, Technical Notes

Handley-Page Bul. Handley-Page Bulletin

Harvard U. Cruft Lab. TR. Harvard University, Cruft Laboratory, Technical Reports

Hawker Siddeley Rev. Hawker Siddeley Review

Hewlett-Packard J. Hewlett-Packard Journal

Hunting Group Rev. Hunting Group Review

Hydraulic Engr. Hydraulic Engineer

IAS Preprint. Institute of the Aeronautical Sciences, Sherman M. Fairchild Fund Preprint

IAS, SMF Fund Paper. Institute of the Aeronautical Sciences, Sherman M. Fairchild Fund Paper

IATA Bul. International Air Transport Association Bulletin

ICAO Bul. International Civil Aviation Organization Bulletin

IME Proc. (A). Institution of Mechanical Engineers, Proceedings (A)

INCO. (International Nickel Company, Inc.)

Ind. & Eng. Chem. Industrial and Engineering Chemistry

Ind. Quality Control. Industrial Quality Control

Indian AF Quart. Indian Air Force Quarterly

Indian Airman

Indian Skyways

Institut Français du Transport Aérien, Res. Paper. Institut Français du Transport Aérien, Research Paper

Instrumentation

Instruments

Interavia (Monthly)

Interchem. Rev. Interchemical Review

Internatl. Nickel Devel. & Res. Div. Tech. Bul. International Nickel Company, Development & Research Division, Technical Bulletins

Ireland, Meteorological Serv., Geophys. Pubs. Ireland, Meteorological Service, Geophysical Publications

J. Acoustical Soc. Am. Journal of the Acoustical Society of America

J. ACS. Journal of the American Chemical Society

J. Aero. Sci. Journal of the Aeronautical Sciences

J. Air Law & Commerce. Journal of Air Law & Commerce

J. Appl. Mech. Journal of Applied Mechanics

J. Appl. Phys. Journal of Applied Physics

J. ARS. Journal of the American Rocket Society

J. Atmos. & Terrestrial Phys. Journal of Atmospheric & Terrestrial Physics

J. Av. Med. Journal of Aviation Medicine

J. Brit. Interplanetary Soc. Journal of the British Interplanetary Society

J. Eng. Educ. Journal of Engineering Education

J. GAPAN. Journal of the Guild of Air Pilots and Air Navigators

J. Helicopter Assn. Gt. Brit. Journal of the Helicopter Association of Great Britain

J. Indian Inst. Sci. Journal of the Indian Institute of Science

J. Inst. Navigation. Journal of the Institute of Navigation

J. Inst. Transp. Journal of the Institute of Transport

J. ISA. Journal of the Instrument Society of America. In: **Instruments**

J. Japan Soc. Appl. Mech. Journal of the Japan Society for Applied Mechanics

J. London Math. Soc. Journal of the London Mathematical Society

J. Math. & Phys. Journal of Mathematics and Physics

J. Mech. & Phys. Solids. Journal of the Mechanics and Physics of Solids

J. Meteorology. Journal of Meteorology

J. RAeS. Journal of the Royal Aeronautical Society

J. Sci. & Ind. Res. Journal of Scientific and Industrial Research

J. Sci. Instr. Journal of Scientific Instruments

J. Sci. Res. Journal for Scientific Research

J. SLAE Journal of the Society of Licensed Aircraft Engineers (incorporating The Technical Instructor)

J. Southern Calif. Meter Assn. Journal of the Southern California Meter Association. In: **Instruments**

J. Southern Res. Journal of Southern Research

J. Space Flight. Journal of Space Flight

Japan, NCB Rep. Japan, Numerical Computation Bureau, Reports

Japan Sci. Rev. Japan Science Review (Engineering Sciences)

Jet Age

Kyushu U., Japan, Res. Inst. Appl. Mech. Rep. Kyushu University, Japan, Research Institute for Applied Mechanics, Reports

La. State U. Eng. Exp. Sta. Bul. Louisiana State University, Engineering Experiment Station, Bulletin

Lenkurt Demodulator

Lockheed Aircraft Rep. Lockheed Aircraft Corporation, Reports

The Log

Lubrication

Mach. Des. Machine Design

Mag. of Magnesium. Magazine of Magnesium

Marconi Rev. Marconi Review

Martin Star

Materials & Methods

Mech. Eng. Mechanical Engineering

Mech. Engr. (India). Mechanical Engineer, Bangalore, India (Journal of the Mechanical Engineering Society, Indian Institute of Science)

Metal Treatment

Metallurgia

Miss. State U. Eng. Res. Sta. Res. Rep. Mississippi State University, Engineering Research Station, Research Reports

Mitteil. Max-Planck-Inst. für Strömungsforschung. Mitteilungen aus dem Max-Planck-Institut für Strömungsforschung (Göttingen)

Modern Metals

Motorola Newsgram

N. C. State Coll., Eng. Sch. Bul. North Carolina State College, Engineering School Bulletin

Natl. Acad. Sci., NRC Rep. National Academy of Sciences of the United States, National Research Council, Reports

Natl. Assn. State Av. Off. Papers. National Association of State Aviation Officials, Papers

Naval Av. News. Naval Aviation News

Navigation

Netherlands, Mathematisch Centrum, Amsterdam, Rep. (Report)

Netherlands, NLL Rep. (Rep. & Trans.) Netherlands, Nationaal Luchtvaartlaboratorium (National Aeronautical Research Institute), Amsterdam, Reports (Reports and Transactions)

New Frontiers

New Zealand Flying

NFPA Bul.; Papers; Rep. National Fire Protection Association, Bulletins; Papers; Reports

NFPA Comm. Av. & Airport Fire Protection Bul.; Rep. National Fire Protection Association, Committee on Aviation and Airport Fire Protection, Bulletins; Reports

North Amer. Av. Special Res. Rep. North American Aviation Corporation, Special Research Reports

NYU Res. Rev. New York University, College of Engineering, Research Review

O. State U. Eng. Exp. Sta. News. The Ohio State University, Engineering Experiment Station, News

Ordnance

Ore. State Coll. Eng. Exp. Sta. Bul. Oregon State College, Engineering Experiment Station, Bulletin

Organic Finishing

The Oscillographer

Papers in Meteorology & Geophys. Papers in Meteorology and Geophysics

Pegasus

Philips Tech. Rev. Philips Technical Review

Philos. Mag. Philosophical Magazine

Curtiss-Wright Cuts Cost of WRIGHT J-65 Jet Engines

BY USING DUCTILE IRON

CURTISS-WRIGHT CORPORATION has slashed unit cost and made mass production possible by redesign of the center main bearing support . . .

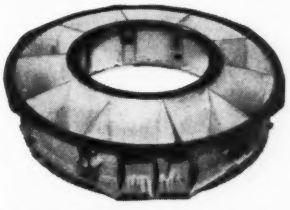
As originally designed experimentally abroad the part required 1200 hours machining time on a one-piece aluminum forging, using Keller duplicating machines. There weren't enough duplicators in the United States to turn out the quantities required. But engineers from the WRIGHT AERONAUTICAL DIVISION of C-W simplified it into inner and outer rings of Ductile Iron. Weldability of Ductile Iron was utilized in joining ten "18-8" chromium-nickel stainless steel struts to the rings.

Ductile Iron provides greater strength and toughness at moderately elevated temperatures. Moreover, it has good casting qualities and is readily machined. The rings are finish-machined to provide an air passage with an accuracy of .005", and casting tolerances are 0.030" on the 3-foot ring diameter. Eliminating complex contour machining, the WRIGHT redesign accelerates output and helps reduce unit cost to about one-tenth that of carving supports from pancake forgings as was called for in the original design.

Counsel and data on Ductile Iron are freely available. Send us details of your prospective uses, so that we may offer a list of sources from some 100 authorized foundries now producing DuctileIron under patent licenses.

EMBLEM OF INCO SERVICE

Sapphire Turbo-Jet Engine Main Bearing Support original design, machined experimentally from a one-piece aluminum forging.



The Redesigned Support is now used in WRIGHT J-65 engines that power Republic Thunderstreak Fighters built by REPUBLIC AVIATION CORP.

This assembled unit comprises (below) (a) inner ring and (b) outer ring, both cast in Ductile Iron by Engineered Casting Division of AMERICAN BRAKE SHOE COMPANY, Mahwah, N. J., connected with (c) struts of "18-8" stainless steel.

(a)

(b)

(c)

THE INTERNATIONAL NICKEL COMPANY, INC. 67 WALL STREET NEW YORK 5, N. Y.

Photogrammetria

Photogrammetric Eng. Photogrammetric Engineering

Photographic Eng. Photographic Engineering

Princeton U. Aero. Eng. Lab. Rep. Princeton University, Aeronautical Engineering Laboratory, Report

Proc. Cambridge Philos. Soc. Proceedings Cambridge Philosophical Society

Proc. IEE, Part I. Proceedings of the Institution of Electrical Engineers, Part I (General)

Proc. IEE, Part II. Proceedings of the Institution of Electrical Engineers, Part II (Power Engineering)

Proc. IEE, Part III. Proceedings of the Institution of Electrical Engineers, Part III (Radio and Communication Engineering)

Proc. IRE. Proceedings of the Institute of Radio Engineers

Proc. London Math. Soc., 2nd Ser. Proceedings of the London Mathematical Society, 2nd Series

Proc. London Math. Soc., 3rd Ser. Proceedings of the London Mathematical Society, 3rd Series

Proc. Royal Soc. (Edinburgh). Proceedings of the Royal Society (Edinburgh)

Proc. Royal Soc. (London), Ser. A. Proceedings of the Royal Society (London), Series A (Mathematical and Physical Sciences)

Prod. Eng. Product Engineering

Prof. Engr. Professional Engineer

Purdue U. TR. Purdue University, Technical Reports

Quadrangle

Quart. Appl. Math. Quarterly of Applied Mathematics

Quart. J. Mech. & Appl. Math. Quarterly Journal of Mechanics and Applied Mathematics

Radio & TV News. Radio & Television News

Radio-Electronic Eng. Sect. Radio-Electronic Engineering Section, In: **Radio & TV News**

Radio Tech. Comm. Aeronautics, Papers. Radio Technical Commission for Aeronautics

RAND Corp. Transl. The RAND Corporation, Translations

RCA Rev. RCA Review

La Recherche Aéronautique (Paris)

Republic Av. Rep. Republic Aviation Corporation, Reports

Rev. Sci. Instr. Review of Scientific Instruments

Revista de Aeronáutica (Madrid)

Reynolds Metals Tech. Adviser. Reynolds Metals Technical Adviser

La Ricerca Sci. La Ricerca Scientifica (Rome)

Rivista Aeronautica (Rome)

Rockets

Rolls-Royce Bul. Rolls-Royce Bulletin

Ryan Reporter

Saab Sonics (Sweden)

Saab TN. Saab Technical Notes

SAE Aero. Info. Rep. Society of Automotive Engineers, Aeronautical Information Report

SAE J. SAE Journal

SAE Preprints. Society of Automotive Engineers, Preprints

Sailplane & Glider.

Saro Prog. Saro Progress

Sheet Metal Ind. Sheet Metal Industries

Shell Av. News. Shell Aviation News

Skyline. (North American Aviation, Inc.)

Skyways

Soaring

Solar Blast

SPE J. Society of Plastics Engineers, Journal

Sperry Gyroscope Rep. Sperry Gyroscope Company, Reports

Sperry Rev. Sperry Review

Sperryscope

Stanford Res. Inst. Res. Ind. Stanford Research Institute, Research for Industry

State Coll. Ia. Eng. Exp. Sta. TR. State College of Iowa, Engineering Experiment Station, Technical Reports

Steel Horizons

Steel Processing

Stockholm, Kungliga Tekniska Högskolan, Inst. för Flygteknik, TN. Stockholm, Kungliga Tekniske Högskola, Institutionen for Flygteknik, Technical Notes

Structural Engr. Assn. Calif. Rep. Structural Engineers Association of California, Reports

Sweden, Flygtekniska Försöksanstalten, FFA Meddelande

Taylor Tech. Taylor Technology

Tech. et Sci. Aéronautiques. Technique et Science Aéronautiques (Paris)

Tech. Rev. Technology Review

Tele-Tech

Tool Engr. Tool Engineer

Trans. ASME. Transactions of the American Society of Mechanical Engineers

Trans. Inst. Welding. Transactions of the Institute of Welding

Trans. Soc. Inst. Tech. Transactions of the Society of Instrument Technology

Transp. & Commun. Rev. Transport and Communications Review

Transport (India)

Trend in Eng. The Trend in Engineering

U. Ark. Engr. Exp. Sta. Bul. University of Arkansas, Engineering Experiment Station Bulletin

U. Calif. Pubs. in Eng. University of California, Publications in Engineering

U. Ill. Bul. University of Illinois, Bulletins

U. Ill. Eng. Exp. Sta. Bul.; TR. University of Illinois, Engineering Experiment Station Bulletin; Technical Report

U. Mich. Eng. Res. Inst. Rep. University of Michigan, Engineering Research Institute, Report

U. Minn. Inst. Tech. Dept. Aero. Eng., Res. Rep. University of Minnesota, Institute of Technology, Department of Aeronautical Engineering, Research Reports

U. Toronto Inst. Aerophys. Rev.; Rep. University of Toronto, Institute of Aerophysics, Review; Reports

U. Wash. Eng. Exp. Sta. Bul.; Reprints. University of Washington, Engineering Experiment Station, Bulletins, Reprints

U. Wis. NRL Dept. Chem. Rep. University of Wisconsin, Naval Research Laboratory, Department of Chemistry, Reports

United Air Lines News

U.S., Bur. Mines Bul.; Rep. Invest. United States, Bureau of Mines, Bulletin; Report of Investigations

U.S., CAA TDR. United States, Civil Aeronautics Administration, Technical Development Reports

U.S., Forest Prod. Lab. Rep. United States, Forest Products Laboratory, Madison, Wis., Reports

U.S., NACA Rep.; RM; TM; TN. United States, National Advisory Committee for Aeronautics, Report; Research Memorandum; Technical Memorandum; Technical Notes

U.S., NAES Rep. United States, Naval Air Experiment Station, Reports

U.S., NAVORD Rep. United States, Naval Ordnance, Reports

U.S., Navy Dept. BuAer RDR. United States, Navy Department, Bureau of Aeronautics, Research Division Reports

U.S., Navy Dept., David W. Taylor Model Basin, Rep.; Transl. United States, Navy Department, David W. Taylor Model Basin, Reports; Translations

U.S., NBS J. Res. United States, National Bureau of Standards, Journal of Research

U.S., NBS Sum. TR. United States, National Bureau of Standards, Summary Technical Reports

U.S., NBS Tech. News Bul. United States, National Bureau of Standards, Technical News Bulletin

U.S., NRL Rep. United States, Naval Research Laboratory, Reports

U.S., ONR Res. Rep. United States, Office of Naval Research (monthly), Research Report

U.S., ONR Special Devices Cen. TR. United States, Office of Naval Research, Special Devices Center, Technical Reports

U.S., Weather Bur. Mo. Weather Rev. United States, Weather Bureau, Monthly Weather Review

USAF AMC Eng. Div. Aero Med. Lab. TR. United States Air Force, Air Materiel Command, Engineering Division, Aero Medical Laboratory, Technical Reports

USAF APG Rep. United States Air Force, Air Proving Ground, Reports

USAF MATS Rep.; Papers. United States Air Force, Military Air Transport Service, Reports; Papers

USAF SAM Rep. United States Air Force, School of Aviation Medicine, Reports

USAF TR. United States Air Force, Technical Reports

U.S. Air Serv. U.S. Air Services

U.S. Armed Forces Med. J. United States Armed Forces Medical Journal

U.S. AEC Rep. United States Atomic Energy Commission, Reports

U.S. Naval Inst. Proc. United States Naval Institute Proceedings

VPI Eng. Exp. Sta. Ser. Bul. Virginia Polytechnic Institute, Engineering Experiment Station Series Bulletin

W. U. Tech. Rev. Western Union Technical Review

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Welding J. Welding Journal
Welding J. Res. Suppl. Welding Journal, Research Supplement
Welding Res. Welding Research (London)
Weltraumfahrt (Frankfurt am Main)
Western Av. Western Aviation
Westinghouse Engr. Westinghouse Engineer
Whites' Av. Whites' Aviation
Wireless World
WMO Bul. World Meteorological Organization Bulletin

ZAMM. Zeitschrift für angewandte Mathematik und Mechanik (Berlin)
ZAMP. Zeitshrift für angewandte Mathematik und Physik (Zurich)
ZFW. Zeitschrift für Flugwissenschaften (Braunschweig)
Zurich, ETH Inst. für Aerodynamik, Mitteilungen. Zurich, Eidgenössische Technische Hochschule, Institut für Aerodynamik, Mitteilungen (Switzerland)

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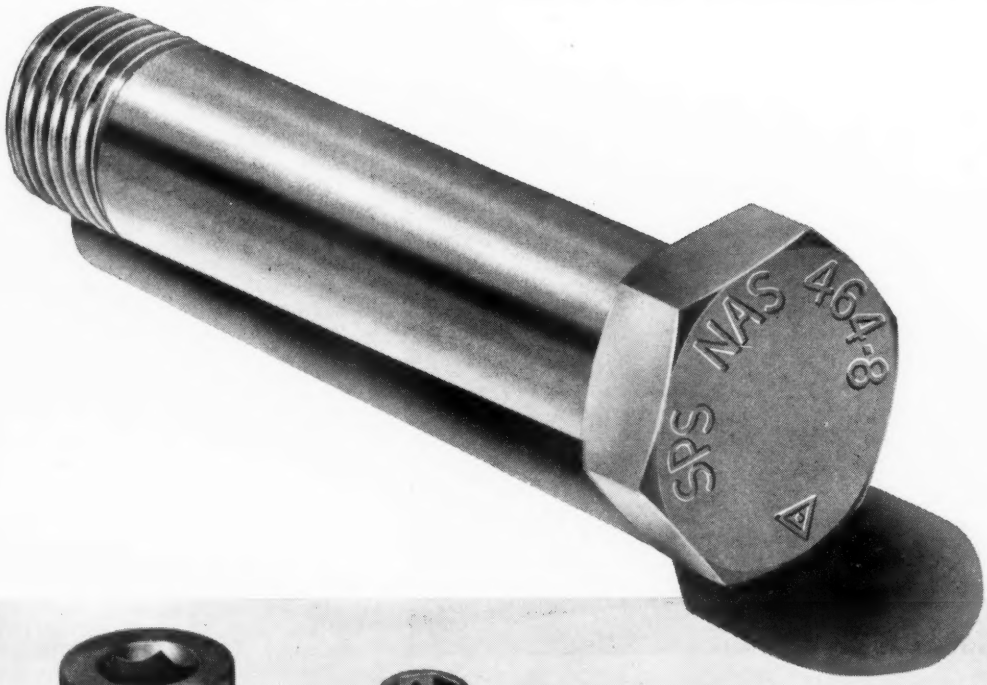

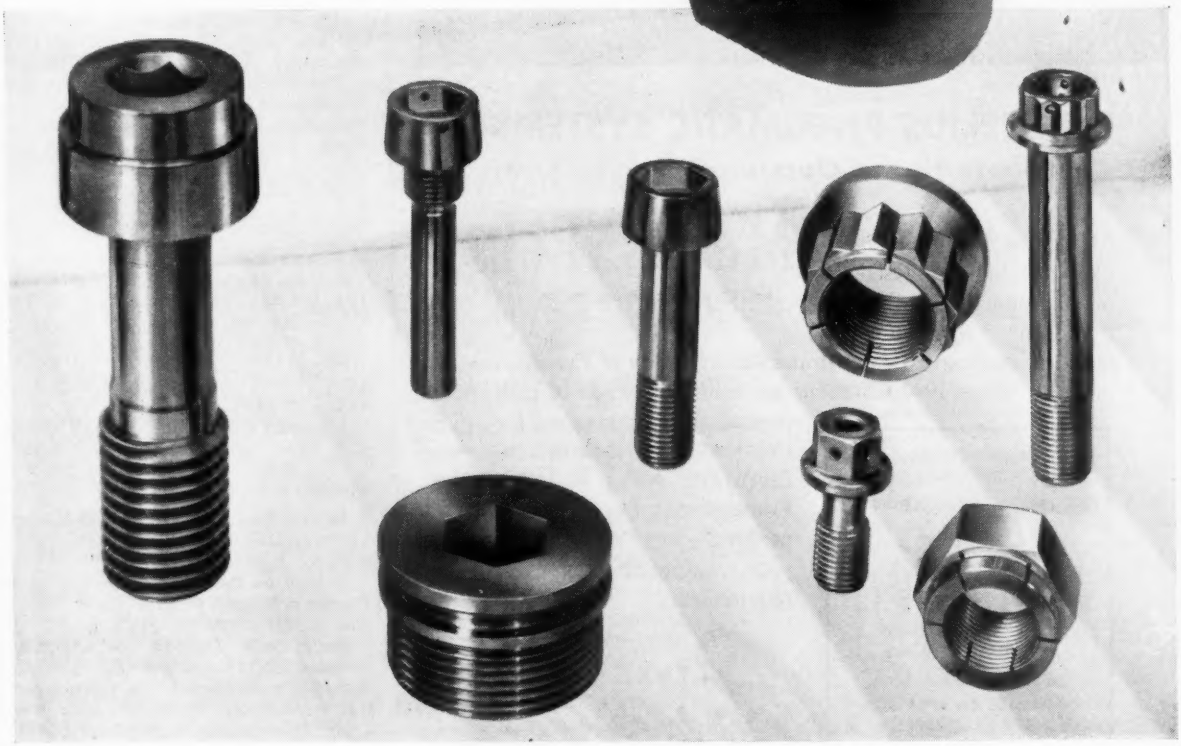

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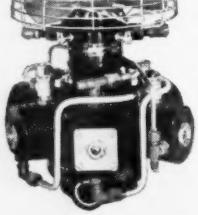

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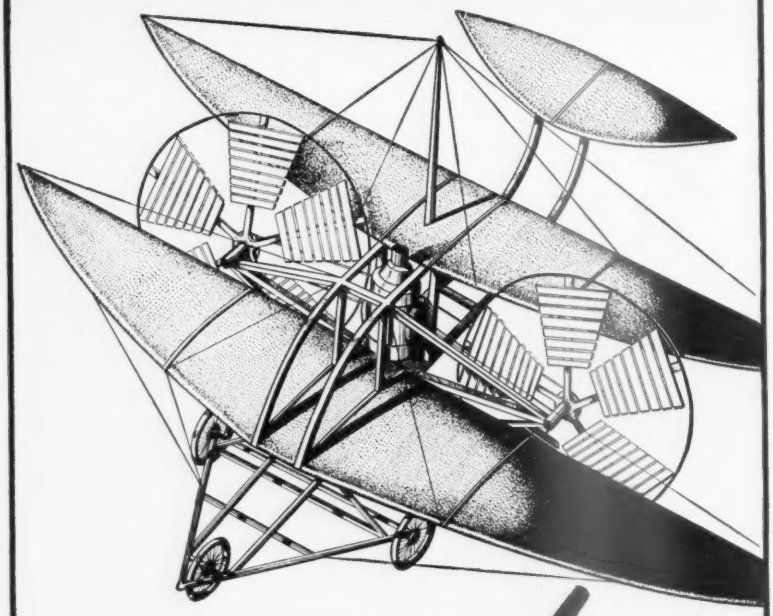

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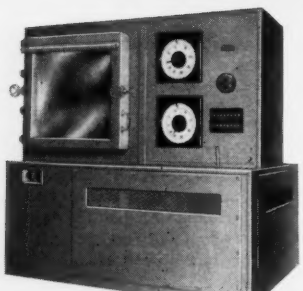

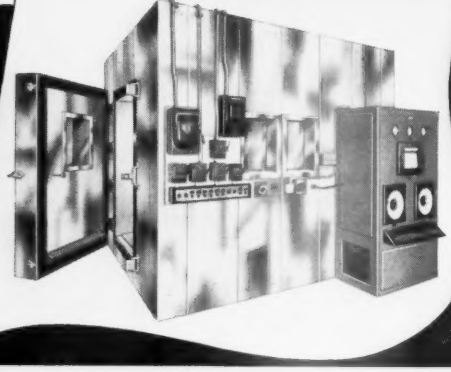

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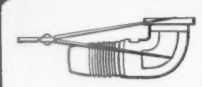

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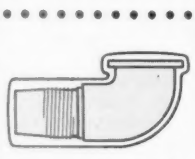

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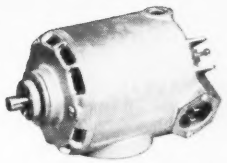

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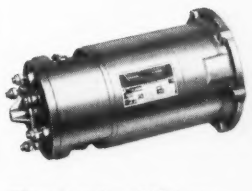

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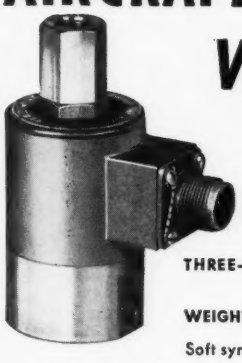

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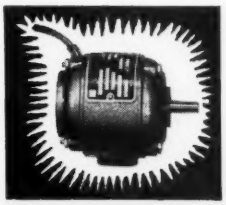

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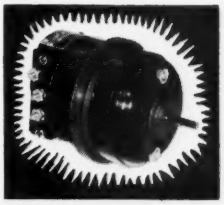

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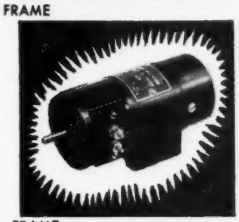

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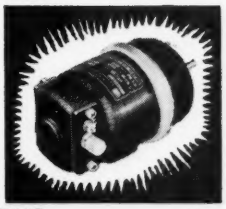

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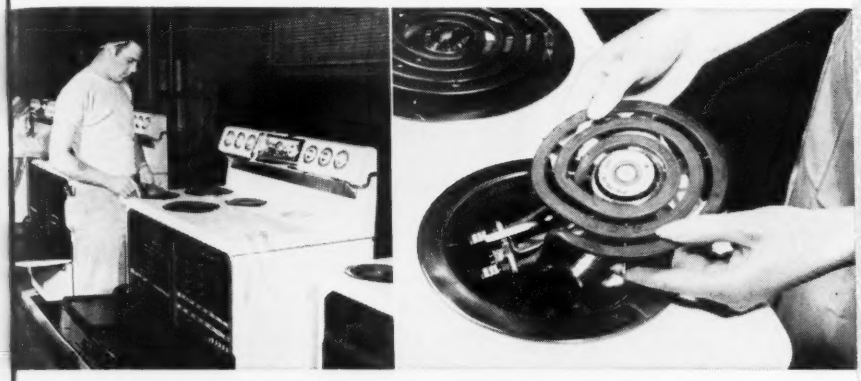


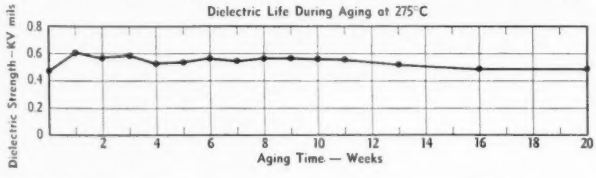
Engineers have been working for years to make a heat control system for electric range surface units that would forever banish pot watching. But it took Westinghouse, using a bit of Silastic, a thermistor, and a few relays and vacuum tubes, to perfect the "Electronic Eye." This heat control system regulates the temperature so accurately that food can be warmed, boiled or fried without danger of burning or scorching—even if all the water is boiled away. The heart of the temperature measuring device, the thermistor, is embedded in Silastic paste for protection and heat transfer. Flexible Silastic insulated cable is used to connect the thermistor to the exterior wiring, and the Electronic Eye itself is isolated in the center of a flexible Silastic diaphragm. The Silastic components have stood up under exposure to boiling water, oil, grease, coffee and syrup, as well as accelerated life testing equivalent to 15 years of actual service.

Performance proves...

SILASTIC works

where other materials fail!

Many of the most able designers, like those Westinghouse men who made automatic cooking a practical reality, save time and money by trying Silastic first when they need rubbery properties at temperatures far above or below the limits of any ordinary rubber. And exceptional stability at both high and low temperatures is combined in Silastic with excellent resistance to outdoor weathering and good resistance to a variety of hot oils and chemicals. Further proof of the inherent stability of Silastic is given in this small graph showing the effect of aging at 275°C (527°F) on the dielectric strength of Silastic.



Dielectric strength measured with ¼ inch electrodes in air on two layers of Silastic R Tape, for example, average 0.475 KV per mil. After 20 weeks of continuous aging at 275°C with both surfaces exposed in an air circulating oven, dielectric strength gradually decreased from a high of 0.601 to 0.485 KV per mil.

That's the kind of performance that makes Silastic, the Dow Corning silicone rubber, unique among all rubbery materials. When you need rubbery properties at temperatures above 150°F or below —40°F, or excellent dielectric properties in a resilient and flexible material ***specify Silastic.***

*T. M. REG. U. S. PAT. OFF.

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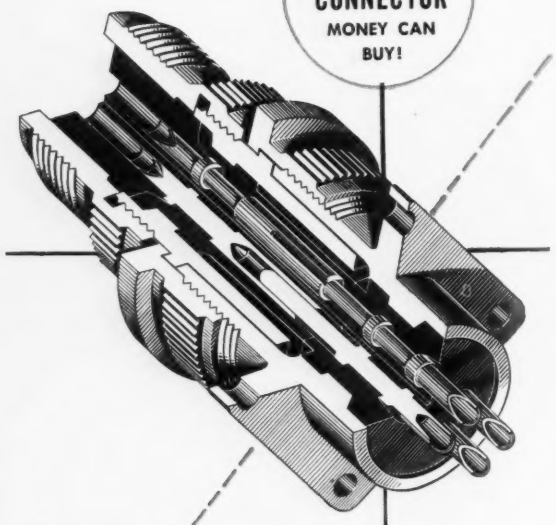

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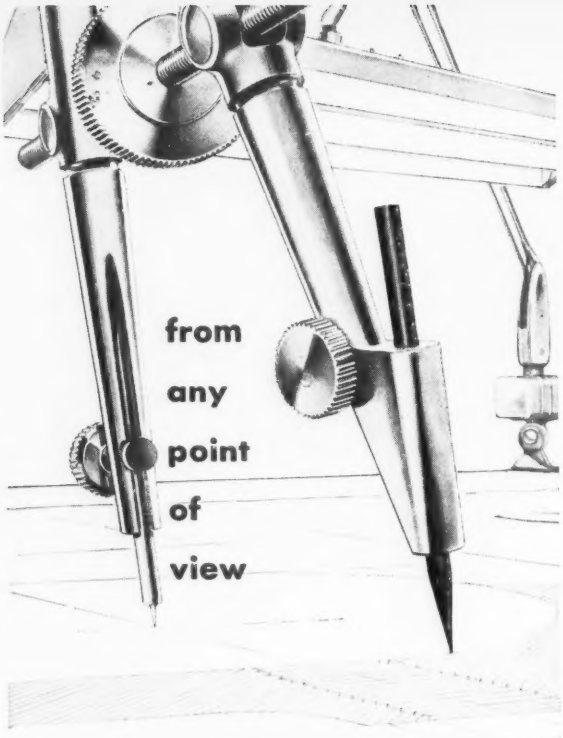

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Aeronautical Reviews — BOOKS

Book Notes

AERODYNAMICS

The Theory of Homogeneous Turbulence. G. K. Batchelor. London, New York, Cambridge University Press, 1953. 197 pp., diagrs. $5.00.

This volume is the first in a series of Cambridge Monographs on Mechanics and Applied Mathematics. Later volumes are to include works on turbulent shear flow, hydrodynamic stability, and high-speed flow. Dr. Batchelor, who is Lecturer in Mathematics in the University of Cambridge, has intended this treatise to fill the need for a systematic and complete account of the established knowledge of turbulence. In the selection of experimental data and in the assessment of theoretical contributions, he has leaned heavily on the great amount of research carried out at Cambridge by himself and his colleagues. The exception to completeness is in the exclusion of all work requiring a Lagrangian, or motion-of-a-particle, description of the flow. Thus no mention of the important problem of turbulent diffusion will be found. The manner of presentation has been chosen, not with an eye to the needs of mathematicians or physicists or any other class of people, but according to what is best suited, in the author's opinion, to the task of understanding the phenomenon. Mathematical analysis is used extensively, and descriptive physics have been employed where they would help the understanding. In Chapter 1, the author introduces the study of homogeneous turbulence, formulates the problem mathematically, and gives a brief history of the subject. Chapters 2 and 3 are concerned with the mathematical presentation of the field of turbulence and the kinematics of homogeneous turbulence (velocity and vorticity correlation, spectrum tensors, symmetry conditions, isotropic turbulence). Some linear problems—simple harmonic oscillator subject to a random force, passage of a turbulent stream through wire gauze, effect of sudden distortion of a turbulent stream—are discussed. The remaining four chapters have as their topics: The General Dynamics of Decay, The Universal Equilibrium Theory, Decay of the Energy-Containing Eddies, and The Probability Distribution of $\mathbf{u}(\mathbf{x})$. The bibliography at the end of the work contains over 170 references, some as recent as 1952. The book concludes with a brief index of subjects and names. Dr. Batchelor's account of homogeneous turbulence should prove of great value in the field of aeronautics, as well as meteorology, oceanography, astrophysics, and chemical engineering.

AIR TRANSPORTATION

The Basis of a Development Program for Colombia. Report of a Mission Headed by Lauchlin Currie and Sponsored by the International Bank for Reconstruction and Development in Collaboration with The Government of Colombia. Baltimore, The Johns Hopkins Press, 1952. 642 pp., maps, tables. $5.00.

This report covers a wide range of subjects, but the central consideration is the best possible utilization of Colombia's physical and financial resources, and the ways in which both government and private agencies can contribute to that end. Of particular interest are chapters 8 and 21, which are concerned with air transportation. In Chapter 8 are given statistical data on airlines, airports, and equipment, together with some historical notes. Chapter 21 contains recommendations for a program of administrative reorganization and government regulation for the improvement of aviation facilities and equipment; capital requirements are estimated. Other chapters of interest are devoted to economics, industry, and service transportation.

AIRPORTS

Proceedings of the 1952 Conference Airport Management and Operations. Held at the Extension Study Center, The University of Oklahoma, North Campus, October 9–10, 1952. Sponsored by Flight Magazine and The University of Oklahoma with the Co-Operation of the Civil Aeronautics Administration. Norman, Okla., University of Oklahoma, 1952. 102 pp.

Text and discussions of the following papers: The Present Blocks to Civil Airport Development, Walter E. Betsworth. Helicopters Are Coming, Hans Weischel, Jr. Can the Airlines Use the Helicopter? L. S. Wigdortchik. The NACA and Civil Aviation Problems, John F. Victory. The Career Airport Manager and His Future, B. M. Doolin. Conference Board of Inquiry: "Is Military Aviation Kicking Civil Aviation Around?" William M. Berry. A Report of the Industry, Donald W. Nyrop. The Airport Problems of the Local Service Airline, Paul Rodgers. Your Airport—A Public Trust, Warren A. Hope. Sales Promotion for Operators. Concessions and Finances, Bennett H. Griffin, The Margin of Safety—A Close Look at Safety Over the Airport, John M. Chamberlain. General Aviation One Year Later, John H. Burke.

CONVERTIBLE AIRCRAFT

Proceedings of the Second Convertible Aircraft Congress, Philadelphia, December 12, 1952. Sponsored by the Pioneers in Convertible Aircraft in Cooperation with the Philadelphia Sections of the American Helicopter Society and the Institute of the Aeronautical Sciences. New York, IAS, 1953. 143 pp., illus., diagrs. $5.00 ($3.00 to Members of the IAS and AHS).

Contents: New Comments on Configurations, Louis de Monge de Franeau. Super Speed Converti-Planes for Military and Commercial Use, Alfred I. Roman. Composite Aircraft with Rotary and Fixed Wing Components, J. A. J. Bennett. The Operable Model of the S.S.S. Convertoplane, G. P. Herrick. Jet Propulsion for Convertaplanes, David C. Prince. Development of Convertiplane, Grover C. Loening. Basic Design Philosophy, E. Burke Wilford. The High-Speed Convertiplane, F. M. Gloeckler. Movies of Free-Flight Model Convertiplane, L. M. Patrick. Airlines Appraisal of Convertible Aircraft, G. H. Aldrich. The Position of the Convertible Aircraft in Army Aviation, William B. Bunker. Impressions of a Newcomer, C. E. Rosendahl. Medvedeff Monocopter (Convertiplane), N. J. Medvedeff. When Will the Converted Plane Come, Antoine Gazda. The Convertaplane—A Historical Resume and Definition, E. K. Liberatore. Listing of Sponsors, Guests, Registrants, and Participants at the Congress.

MANAGEMENT

A Short-Term Training Program in an Aircraft Engine Plant. (U.S., Department of Labor, Women's Bureau, Bulletin No. 245.) Washington, Superintendent of Documents, 1953. 11 pp. $0.30.

Engineering Valuation and Depreciation. Anson Marston, Robley Winfrey, and Jean C. Hempstead. 2d Ed. New York, McGraw-Hill Book Co., Inc., 1953. 508 pp. $8.00.

A major revision of Marston and Agg's *Engineering Valuation*, this volume retains all the major subject material, but is totally rewritten, rearranged, and modernized. The text deals with concepts and procedures involved in the appraisal of industrial, commercial, utility, and natural resource properties for which it is desirable that engineers perform the appraisal. There is a new chapter on the rate of return which offers the reader a treatment on fair rate of return. There are detailed discussions on depreciation and service lives with a new approach for appraisal and accounting purposes. There is a more direct and complete treatment of valuation of mines and limited-life enterprises, including a full investigation into the uncertainty of the use of the two-rate Hoskold formula. An increased use of illustrative material has been adopted, and former illustrations have been redone. Figures on price and cost trends have been brought up to date.

MATHEMATICS

Construction and Applications of Conformal Maps. Proceedings of a Symposium Held on June 22–25, 1949, at the Institute for Numerical Analysis of the National Bureau of Standards at the University of California, Los Angeles. Edited by E. F. Beckenbach. (National Bureau of Standards, Applied Mathematics Series No. 18.) Washington, Superintendent of Documents, December 26, 1952. 280 pp., diagrs. $2.25.

Contents: On Network Methods in Conformal Mapping and in Related Problems, R. von Mises.

For Information on IAS Library Service Facilities, see page 95

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Flow Patterns and Conformal Mapping of Domains of Higher Topological Structure, R. Courant. Some Industrial Applications of Conformal Mapping, H. Poritsky. Conformal Maps of Electric and Magnetic Fields in Transformers and Similar Apparatus, G. M. Stein. Conformal Mapping Applied to Electromagnetic Field Problems, Ernst Weber. On the Use of Conformal Mapping in Two-dimensional Problems of the Theory of Elasticity, I. S. Sokolnikoff. Conformal Mapping Related to Torsional Rigidity, Principal Frequency, and Electrostatic Capacity, G. Szegö. Fluid Dynamics, Conformal Mapping, and Numerical Methods, Andrew Vazsonyi. The Use of Conformal Mapping in the Study of Flow Phenomena at the Free Surface of an Infinite Sea, Eugene P. Cooper. An Application of Conformal Mapping to Problems in Conical Supersonic Flows, R. C. F. Bartels and O. Laporte. On the Helmholtz Problem of Conformal Representation, Alexander Weinstein. Some Generalizations of Conformal Mapping Suggested by Gas Dynamics, Lipman Bers. The Use of Conformal Mapping to Determine Flows with Free Streamlines, David M. Young. Conformal Mapping in Aerodynamics, With Emphasis on the Method of Successive Conjugates, I. E. Garrick. On the Convergence of Theodorsen's and Garrick's Method, A. M. Ostrowski. On a Discontinuous Analogue of Theodorsen's and Garrick's Method, A. M. Ostrowski. On Conformal Mapping of Variable Regions, S. E. Warschawski. A Variational Method for Simply Connected Domains, A. C. Schaeffer and D. C. Spencer. Some Remarks on Variational Methods Applicable to Multiply Connected Domains, M. Schiffer and D. C. Spencer. The Theory of Kernel Functions in Conformal Mapping, S. Bergman and M. Schiffer. A New Proof of the Riemann Mapping Theorem, P. R. Garabedian. The Kernel Function and the Construction of Conformal maps, Zeev Nehari. An Approximate Method for Conformal Mapping, Lee H. Swinford. On the Effective Determination of Conformal Mapping, Max Shiffman. The Difference Equation Method for Solving the Dirichlet Problem, P. C. Rosenbloom. Relaxation Methods as Ancillary Techniques, Richard Southwell. Conformal Invariants, Lars V. Ahlfors and A. Beurling. On Subordination in Complex Variable Theory, E. F. Beckenbach and E. W. Graham. Asymptotic Developments at the Confluence of Boundary Conditions, Hans Lewy. Monodiffric Functions, Rufus Isaacs. Recent Contributions of the Hungarian School to Conformal Mapping, G. Szegö. Bibliography of Numerical Methods in Conformal Mapping, W. Seidel.

Introduction to the Theory of Stochastic Processes Depending on a Continuous Parameter. Henry B. Mann. (National Bureau of Standards, Applied Mathematics Series No. 24.) Washington, Superintendent of Documents, February 11, 1953. 45 pp. $0.30.

METEOROLOGY

Cloud Forms According to the International Classification. Definitions and Descriptions Approved by the International Meteorological Organization with Photographs of Clouds. Sixth Ed. (incorporating resolutions of Washington, 1947). (Gt. Brit. Meteorological Office, M.O. 233.) New York, British Information Services, 1952. 32 pp., illus. $0.50.

PRODUCTION

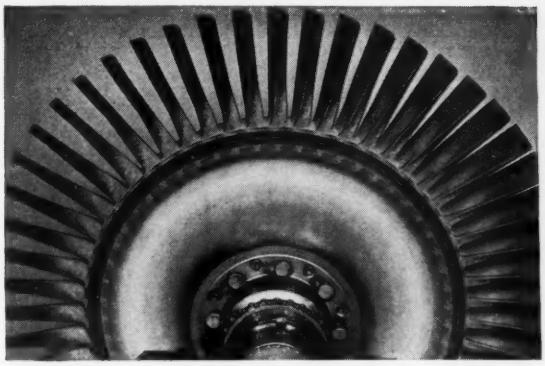
Simplified Drafting Practice. W. L. Healy and A. H. Rau. New York, John Wiley & Sons, Inc., 1953. 156 pp., illus. $5.00.

This book is based on a comprehensive study of drafting practices throughout the General Electric Company. Its purpose is to arouse the interest of engineering and drafting organizations in the substantial savings in time and money that can be obtained by the adoption and extension of simplified practices. To meet this aim, routines and practices of reducing the time and effort required to make drawings are recommended.

(*Concluded on page 128*)

The NIMONICS

high-temperature alloys that offer many useful properties.



HERE IS HOW the Nimonic "80"A blading of a J-42 turbine looks after 500 hours of test running. The blades, according to Pratt & Whitney, are in almost as good condition as they were at the start of the test.

As time passes, you'll hear the Nimonics talked about with increasing frequency.

And with good reason! The Nimonic alloys (we'll discuss two of them individually in a moment) are high-temperature alloys. Their characteristics are frequently sought by aircraft designers.

Let's consider Nimonic "75" (available in sheet only) first. Offering high resistance to oxidation and corrosion, it is particularly useful wherever a limited creep deformation can be tolerated under steady load and at high operating temperatures.

Up to now, Nimonic "75" has been used mainly for nozzle guide vanes, flame tubes and other combustion chamber components in British and American aircraft turbines. But its field, of course, is not strictly limited to these applications. Wherever inlet temperatures push above 1450° F., Nimonic "75" may well be kept in mind. It provides:

- High creep and fatigue strength
- High oxidation resistance at elevated temperatures
- A low coefficient of expansion, similar to mild steel (holds distortion to a relatively low level)

The second of these high-temperature alloys (available in bar stock only) is Nimonic "80"A. This is the standard material used for moving blades in nearly every production aircraft turbine in Great Britain. It is the material used, too, for turbine blades of Pratt & Whitney J-42 Turbo-Wasps, the jets that have flown more than 150,000 hours *without a single turbine blade failure.* The picture above shows the excellent condition of these blades after a 500-hour test run.

Essentially a forging alloy, Nimonic "80"A compares favorably with other alloys designed for long periods of high-temperature service under stress. While its superior creep resistance is largly responsible for its suitability as a blade material, its high oxidation resistance at elevated temperatures and its high fatigue strength under stress are also important.

Both of these Nimonic alloys have working qualities that greatly increase their range of usefulness to the designer. They can be machined by commonly-used methods, and with standard equipment. Their toughness and capacity for work-hardening, however, call for careful tool placement, fairly slow cutting speeds and generous use of lubricant.

Welding is readily accomplished by any of these methods: oxy-acetylene, inert gas arc, metallic arc, flash, spot, stitch, seam or butt. Detailed information on procedures is available, and Inco's Technical Service Section will be glad to furnish it upon request.

In fact, when you need help with any metal problem involving high temperatures, call on Technical Service. There's no charge, no obligation.

Consult your Distributor of Inco Nickel Alloys for the latest information on availability from warehouse and mill. Remember, too — it always helps to anticipate your requirements well in advance.

The International Nickel Company, Inc.,
67 Wall Street, New York 5, N. Y.

Approximate Composition

	NIMONIC "75"	NIMONIC "80" A
Carbon	0.08 — 0.15%*	0.10 max.
Manganese	max. 1.00	1.00 max.
Sulfur	max. 0.015*	0.015 max.
Silicon	0.30 — 0.80	1.00 max.
Chromium	19.00 — 21.00	19.00 — 22.00
Titanium	0.25 — 0.50	2.00 — 2.75
Iron	max. 2.00	2.00 max.
Copper	max. 0.50	0.50 max.
Aluminum	max. 0.40	0.90 — 1.50
Nickel	Remainder	Remainder

Inco Nickel Alloys

MONEL® • "R"® MONEL • "K"® MONEL • "KR"® MONEL "S"® MONEL • INCONEL® • INCONEL "X"® • INCONEL "W"® INCOLOY® • NIMONICS® • NICKEL LOW CARBON NICKEL • DURANICKEL®

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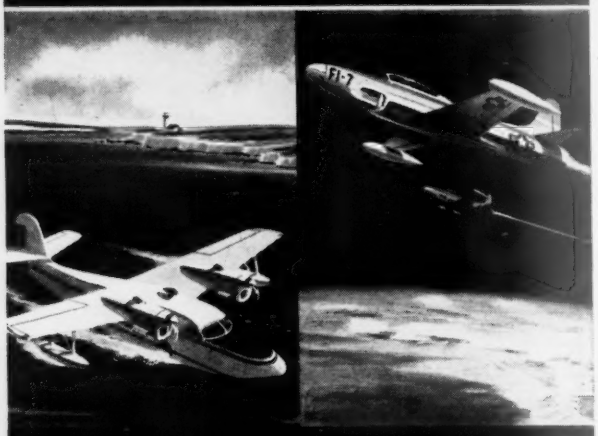

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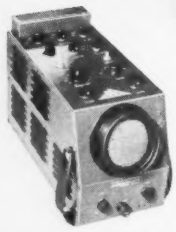

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Wanted

Engineers—Opportunities for employment exist in the Bureau of Aeronautics, Department of the Navy, Washington, D.C. **Aircraft Modification Design Engineer**—GS-12, $7,040 per annum. Determine remedial measures for structural failures of naval aircraft through analysis of accident and structural failure reports; initiate and follow through corrective actions and design changes. **Electronic Engineer (Radio)**—GS-12, $7,040 per annum. Plan, initiate, and supervise research, design, development, and tests and recommend engineering action concerning landing aids for naval aircraft. **Electronic Engineer (Radio)**—GS-12, $7,040 per annum. Responsible for the planning and execution of a subprogram of research, development, and test projects in a part of the interference reduction field which deals mainly and directly with radio-frequency circuitry. **General Engineer (Fuels, Lubricants, and Packaging)**—GS-12, $7,040 per annum. Initiation and planning of effective programs for Navy-Air Force Engineering standardization in the petroleum materials area. Determination of interservice needs, advisory duties to industry, the preparation of basic engineering specifications, and the promulgation of necessary standardization procedures. **Chemical Engineer**—GS-12, $7,040 per annum. As section head, is responsible for the development, evaluation, and service application of fuels, internal coolants, fuel additives, and lubricants for reciprocating, turbojet, gas-turbine, ram-jet, and pulsating-jet aircraft engines. **Electronic Engineer (General)**—GS-12, $7,040 per annum. Design and development of equipment and the prosecution of all activity pertaining to automatic radio-frequency mid-course guidance equipment as applied to pilotless aircraft and guided missiles. **Aeronautical Power Plant Research Engineer**—GS-12, $7,040 per annum. Development of general designs and studies of reciprocating, turbojet, turboprop, ram- and pulse-jet, and rocket engines to be used in subsonic and supersonic land and carrier-based aircraft and guided missiles. Requirements: 3½ years of professional engineering experience are required in addition to a degree. **Aircraft Performance Engineer**—GS-11, $5,940 per annum. Make comprehensive investigations and mathematical calculations of the performance characteristics of aircraft. Compile and issue performance charts for all types Naval aircraft. **Aeronautical Development Engineer (Hydrodynamics)**—GS-11, $5,940 per annum. Under general supervision, performs highly specialized aeronautical engineering work in the field of hydrodynamics in connection with design of Naval aircraft; assists in model and full-scale research and development projects in hydrodynamics for improvement of seaplane operation. Requirements: 2½ years of professional engineering experience in addition to degree. Applications may be submitted on Standard Form 57, Application for Federal Employment, to the Department of the Navy, Bureau of Aeronautics, Personnel Division, Attention PE-202, Washington 25, D.C. The Standard Form 57 is available at U.S. Post Offices or may be obtained by writing to the Personnel Division, Bureau of Aeronautics. Visitors to the Washington area may call at Room 3909 of the Main Navy Building, 19th and Constitution Ave., N.W., Washington D.C.

Aeronautical Engineer—To teach aerodynamics, airplane design, and applied mechanics. Should have M.S. degree and some industrial experience. Salary in rank according to qualifications. Write Department of Mechanical Engineering, Oregon State College, Corvallis, Ore.

482. Assistant or Associate Professor of Aeronautical Engineering—Wanted by engineering college in Philadelphia to teach undergraduate and graduate courses in aerodynamics, aircraft structures, etc. Opportunity for part-time research or consulting practice. In applying, give details of education and experience, also include photograph.

473. Technical Assistant to Sales Manager—Metropolitan area manufacturer of AN parts offers excellent opportunity for upper-level liaison job with sales staff, requiring capacity to analyze industry problems and requirements with relation to manufacturer's products and to supervise development of new parts to meet these requirements by manufacturer's engineering department. Requires graduate Aeronautical Engineer with several years' air-frame design experience, preferably in structures, as well as some additional experience in production engineering or liaison between design engineering and production.

471. Chief of Stress—Rotary-wing aircraft experience. Responsibilities include static and dynamic analysis on high-speed rotorcraft. Minimum experience 5 years; knowledge of CAA and Military requirements necessary. Work on an expanding program with an established company; location Philadelphia area.

470. Staff Aerodynamicist—Minimum B.S. degree in Aerodynamic Engineering or Physics. Field aerodynamics including the ballistics of free-falling objects. Experience in carrying out experiments in wind tunnels, and experience in optimum shapes on guided missiles. Experience: Minimum of 10 years in responsible position involving research and development. Duties: Perform liaison work between other branches of a technical division. Coordinate data with background knowledge to perform critical analysis and evaluation of research and development program.

468. Aircraft Estimator—Growing southwest air-frame manufacturer has opening for engineer with estimating experience. Minimum of 4 years' aircraft experience is required, preferably in detail and contract estimating. Engineering degree is desirable. Management potential is necessary. Examinations will be given to qualify applicants prior to hiring. Excellent future possibilities. Salary commensurate with qualifications.

The number preceding the notices represents the Box Number of the Institute of the Aeronautical Sciences to which inquiries should be addressed.

Available

481. Advertising and Public Relations Manager—B.S. in Engineering and Business Administration, MBA in Marketing. Age 33. Ten years' progressive experience in all phases of industrial promotion: program planning; budgeting and administration; agency and media liaison; space and promotional copy planning, writing, and editing; pamphlets and brochures; and technical publicity. Press, industry, and Government relations. Licensed pilot, mechanic, and radio operator with background in aviation equipment, radio and electronics, and air transport. Desires position offering greater responsibilities and opportunity for advancement.

480. Aeronautical Engineer—S.M.; age 30. Registered Professional Engineer. At present Associate Professor and Head of Aeronautical Engineering Option at small college. Desires position of progressive responsibility either in education or in industry. Location and salary open.

479. Aeromechanical Engineer—B.M.E.; age 34. Broad background in the aircraft industry including guided-missile electromechanical systems development, flight-test research, and stress analysis. Currently engaged as assistant project electromechanical engineer. Accomplishments include direction of missile electrical system design, booster rocket installation design, test equipment design, environmental test program, and flight test programs. Seeking responsible position in missile, aircraft, or allied fields in greater New York City area only. Current salary, over $7,000. Résumé furnished on request.

478. Aeronautical Engineer—B.Sc. (Hon.); 19 years' experience in the industry. Ten years' experience in aircraft accident investigation and prevention work, in which capacity at present is Head of the Branch in another country. Remainder of experience consists of lecturing in aeronautical subjects and aircraft stressing. Also practical experience of measuring aircraft performance when operating from high-altitude airfields and under high ground-surface temperature conditions. Will be available in the United States in August, 1953, and desires position with aircraft design firm or aeronautical college. Details of experience and requisite documents to meet security regulations sent on request.

477. Aeronautical Engineer—Degree of Aeronautical Engineer; age 33. Twelve years' experience in various fields of engineering. Six years in aerodynamics, aircraft design, maintenance, and manufacturing with three leading air-frame builders and USAF. Six years in plant management, operation, engineering, etc., with a major aircraft company and the textile industry. At present, Project Engineer in Plant Engineering. Desires a staff and management position with responsible company in, or related to, the aircraft industry, with salary level over $8,000. Detailed professional history sent on receipt of letter describing specific position.

476. Aeronautical Engineer—Age 43. Desires to represent responsible companies having, and/or seeking, additional Government contracts

with the Air Force, at Dayton, Ohio. Can assure dignified, aggressive, responsible, and complete representation backed by over 20 years of aviation industry experience, including design, flight test, production, executive, and Naval aviation experience at staff level. Just recently released from a tour of active duty with the Navy as Staff Special Projects Officer. Thoroughly familiar with contract negotiation and technical follow-up. List of references, complete résumé furnished upon request.

474. Sales Engineer or Technical Field Representative—B.S., U.S. Naval Academy; A.E., California Institute of Technology. Inactive pilot with experience in all classes of naval aircraft; 15 years' pilot experience with total time of 4,000 hours. Familiar with military agencies and establishments. Military requirements and design experience. Will accept job with any firm desiring West Coast representative. Free to travel. Limited periods acceptable outside United States. Age 42, single.

472. Aeronautical or Mechanical Engineering Professor.—B.S. in A.E., M.S. in M.E. Available for September appointment in college or university located in the South or Southwest. Principal fields of interest—aerodynamics, fluid mechanics, and thermodynamics at either undergraduate or graduate level. Opportunities for research should be available in the above fields.

469. Aeronautical Engineer—Ph.D. degree. Ten years' teaching experience and 5 years' industrial experience. Desires teaching position.

Book Notes

(*Concluded from page 124*)

Among these recommendations are simplified drafting methods, elimination of nonessentials, and extensive use of freehand drawing, drafting aids, and time-savers. Two-hundred-fifty drawings and photographs illustrate the author's thesis—that drafting can be stripped of its frills without surrendering either clarity of presentation or accuracy of dimension.

Contents: Simplification. Eliminating Unnecessary Work. Freehand Drawing. The Use of Symbols. Mechanical Aids. Abbreviations. Arrowless Dimensioning. Examples of Simplified Drafting. Legible Lettering. Tolerances. Use of Instructions. Drawing Forms and Related Routines. Reproduction Processes. Appendix. Index.

RESEARCH

Verslagen en Verhandelingen (Reports and Transactions), Vol. 17, 1952. Amsterdam, Nationaal Luchtvaartlaboratorium, 1953. 169 pp., illus., diagrs.

Contents: Report F 100, Theory and Practice of Flutter Calculations for Systems with Many Degrees of Freedom, A. I. van de Vooren. Report S 402, Theory and Experiments on the Elastic Overall Instability of Flat Sandwich Plates, F. J. Plantema.

Verslagen en Verhandelingen (Reports and Transactions), Vol. 16, 1952. Amsterdam, Nationaal Luchtvaartlaboratorium, 1953. 200 pp., illus., folding charts.

Contents: Report A. 1241, 1950, Methods for Windtunnel Measurements on Models of Vehicles, Vessels and Constructions, A. de Lathouder. Report A. 1210, 1951, On the Determination of the Transition Point from Measurements of the Static Pressure Along a Surface, H. Wijker. Report A. 1204, 1951, Tunnelwall-Interference for Aerofoils and Aerofoil-Fuselage Combinations in a Tunnel with an Octagonal Section for Incompressible Flow, H. G. Loos. Report A. 1269, 1952, Survey of Transition Point Measurements at the NLL, Mainly for Two-Dimensional Flow Over an NACA 0018 Profile, H. Wijker. Report A. 1238, 1950, Ditching Tests on a Model of the Fokker S 13 Aeroplane, J. F. Hengeveld. Report F. 16, 1951, The Direct and the Inverse Problem of Aerofoil Theory. A Method, with Complete Auxiliary Tables, to Obtain Numerical Solutions, R. Timman. Report F. 66, 1950, A Calculation Method for Three-Dimensional Laminar Boundary Layers, Part I, General Theory, R. Timman. Report F. 66, 1951, A Generalization of Prandtl's Equation, A. van Heemert. Report F. 79, 1951, Revised Methods for Routine Calculations of Laminar and Turbulent Boundary Layer of Two-Dimensional Incompressible Flow, J. A. Zaat. Report F. 96, 1951, Spontaneous Oscillations of an Aerofoil due to Instability of the Laminar Boundary Layer, A. I. v. d. Vooren and H. Bergh. Report M. 1866, 1952, The Effect of Notches on the Strength of Aluminium Alloys Under Static Tensile Loading, J. H. Palm. Report S. 313, 1946, Large Deflections of Semi-Oval Rings, A. van Wijngaarden. Report S. 370, 1952, Evaluation of the Theory on the Post-Buckling Behaviour of Stiffened, Flat, Rectangular Plates Subjected to Shear and Normal Loads, W. K. G. Floor and Th. J. Burgerhout. Report V. 1602, 1952, Analysis of the Pitching Motion of an Aeroplane Due to Sideslip, A. J. Marx and J. Buhrman. Report V. 1625, 1952, The Static Longitudinal Stability and Control of an Aeroplane as Affected by the Compressibility of the Air, J. Buhrman and C. M. Kalkman.

SERVOMECHANISMS

Synchros, Self-Synchronous Devices, and Electrical Servo-Mechanisms. Leonard R. Crow. Vincennes, Indiana, The Scientific Book Publishing Co., 1953. 222 pp., illus., diagrs. $4.20.

The purpose of this book is to contribute a broad understanding of the basic fundamental principles underlying the functional operating theory as well as the effective use and application of synchros and allied self-synchronous electrical mechanisms. Structural features are described in whatever detail is necessary for proper understanding of function and application of the many types and forms of self-synchronous devices. Consideration has also been given to the many special synchros and devices that have evolved from the fundamental forms. The author is Director of Research and Development, Universal Scientific Company.

Contents: (1) Synchros: General Information. (2) Single Phase Synchronous Drive Devices. (3) Synchro Control Transformer. (4) Differential Synchros. (5) Instructive Experiments with Synchros. (6) Positional Errors, Error Detection, Servo-Control Units. (7) Two Speed Synchro Drives. (8) Special Applications of Self-Synchronous Devices. (9) Direct Current Self-Synchronous Devices or Position Indicators. (10) Phase Rotation Indicator Step-by-Step Motor and Electrical Gearing. (11) The Power Synchro and the Synchro Tie. (12) Magnesyns and Other Saturable-Core Electrical Servomechanisms.

STRUCTURES

Vnutrennie Napriazheniia Kak Rezerv Prochnosti v Mashinostroenii (Internal Stresses as a Reserve of Strength in Machine Design). I. V. Kudriavtsev. Moscow, Mashgiz, 1951. 278 pp., illus. (In Russian.)

In this book is surveyed the influence of internal (residual) stresses on the strength and durability of machine details that are subjected to variable stresses. Experimental investigations are generalized by means of the theory proposed by the author for the fatigue strength in the combined-stress condition. Technological methods are indicated which create beneficial residual stresses that increase to a large extent the resistance of members to fatigue rupture and quite abruptly decrease the notch sensitivity. The experimental results used by the author are principally the work of Russian investigators and are referred to in a list of 200 references.

Contents: Chapter 1, Classification of Residual Stresses and Existing Criteria for Fatigue Strength in the Combined-Stress Condition. Chapter 2, Theoretical Analysis of the Influence of Residual Stresses on the Fatigue Strength of Steel. Chapter 3, Analysis of Some Special Cases of the Influence of Residual Stresses on the Fatigue Strength of Steel. Chapter 4, On the Influence of the Concentration of Applied and Residual Stresses on the Fatigue Strength of Steel. Chapter 5, Comparison of a Proposed Theory of Fatigue Strength with Available Experimental Data. Chapter 6, Service Hardening as a Means of Increasing the Fatigue Strength Steel Members. Chapter 7, Effectiveness of the Residual Stresses Caused by Service Toughening of Steel Members with Hidden Cracks. Chapter 8, Influence of Thermal Residual Stresses on the Fatigue Strength of Steel. Chapter 9, Case Hardening as a Means of Increasing the Fatigue Strength of Machine Members. Chapter 10, Increasing the Fatigue Strength of Steel by Nitriding. Chapter 11, Influence of Residual Stresses on the Fatigue Strength of Steel Fabrications. Chapter 12, Stability of Residual Stresses with Time and with the Continuous Applications of Variable Loads. General Conclusions. Literature and Sources.

THERMODYNAMICS

Mechanical Engineering Thermodynamics. David A. Mooney. New York, Prentice-Hall, Inc., 1953. 540 pp., illus. $9.35.

This is an introduction to the principles of thermodynamics and their applications. Descriptive matter on heat engines is included for those who have not studied the subject. The reader is presumed to have a knowledge of college physics and mathematics. The author is Principal Mechanical Engineer, Jackson and Moreland, Engineers.

Contents: (1) Introduction. (2) Work. (3) Temperature and Heat. (4) Properties of Systems. (5) The First Law of Thermodynamics. (6) Flow Processes—First Law Analysis. (7) The Second Law of Thermodynamics. (8) Basic Applications of the Second Law. (9) Properties of Pure Substances. (10) Tabulated Properties—Steam Tables. (11) Properties of Gases. (12) Properties of Gaseous Mixtures. (13) Process Calculations for Stationary Systems. (14) Vapor Cycles—The Rankine Cycle. (15) Vapor Cycles—More Efficient Cycles. (16) Gas Cycles. (17) Fluid Flow—Nozzles and Orifices. (18) Turbines. (19) Reciprocating Expanders and Compressors. (20) The Steam Engine. (21) Gas Compression. (22) Combustion Processes—First Law Analysis. (23) Internal Combustion Power Plants. (24) Refrigeration. (25) Air-Water Vapor Mixtures.